Yukon River Basin Study
Project Report: Energy No. 3

THE INVENTORY OF YUKON HYDROELECTRIC SITES

A Review of Investigations Carried Out Between 1960 and 1983

Commissioned by Northern Canada Power Commission
on Behalf of the Yukon River Basin Committee

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This report was prepared as a background paper for the Energy Work Group. Please refer to the Final Study Report for the views of the Yukon River Basin Study Committee.

SUMMARY

A review has been made of the available reports on hydroelectric investigations and studies in the Yukon Territory and in the B.C. portion of the Yukon River Basin carried out over the last 25 years. These have been summarized and evaluated relative to standards proposed as adequate for an up-to-date and reliable inventory of potential projects (Tables 4-1, 4-2, 4-3 and Appendix C). Where possible the findings of earlier studies have been compared with recent and more complete studies for confirmation or difference (p 3-9).

The review has included assessment of project importance and the requirement for upgrading and updating studies and their input data. A tabulation of sites has been included indicating approximate ratings for importance and study adequacy (Tables 5-1 and 5-2).

FINDINGS AND CONCLUSIONS

About 100 hydro projects have been identified in the Basin. Some 25 of these, including 12 in British Columbia, have not been studied to a level permitting assessment of their realistic potential.

Sixty-five potential projects have been investigated by various groups in the 1960's and 1970's to differing levels of study ranging from purely office studies to pre-feasibility standard. This patchwork inventory has input data and study depth deficiencies which, together with the need for updating and many socio-environmental studies, make it generally inadequate for long or short term resource planning.

Another 10 sites have been studied in the last five years to levels adequate to confirm technical viability and relative attractiveness, so that informed decision is possible on the choice of a project or projects for further studies. For most of these potential projects preliminary socio-environmental studies have been carried out.

Other sites, including those suitable for mini hydro development await future discovery.

Comparison of the findings of the few recent detailed site studies confirmed those of earlier reports on less than half the sites, suggesting the need for upgrading and updating the latter.

The projects assessed in this review fall roughly into three groups as follows:

1960 - 1966 by Water Resources Branch, Dept. of Northern Affairs and National Resources	Group 1	Mainly mega projects including those on the Yukon River main stem and in the north.
1968 - 1978 by various consultants	Group 2	Projects of different sizes mainly in south central Yukon.
1979 - 1983 by various consultants	Group 3	Projects in south central Yukon seen suitable to meet early developing loads.

As can be seen from the following tabulation, the Group 2 projects are relatively small, with an average installed capacity of less than 10% of the Group 1 project average. Some twenty of the latter comprise almost 75% of the Yukon hydroelectric potential and, since most provide relatively low cost electric power, it is not surprising that Group 1 is found to contain a preponderance of the most important projects.

Yukon Basin Hydroelectric Inventory Review Summary

Study Group	Number of Potential Projects	Aggregate(1) Capacity of Projects MW	Average Project Capacity MW	Importance of Projects in Group	Study Factors Most in Need of Revision and Updating	Remarks
Group 1 1962-1966	20(2)	6,700	335	Most are of Average to Major Importance	Design update Socio-environmental	Excludes diversion projects
Group 2 1968-1978	41	1,300	32	Most are Minor to Average Importance	Field work Hydrology Estimating Study depth Socio-environmental	In addition, on more than 50% of projects Design update, topography and geotechnical factors need upgrading
Group 3 1980-1983	9	1,100	122	Most are of Average to Major Importance	Generally adequate	Some sites require minor study upgrading

Notes: 1) Removal of alternative duplicating projects reduces total capacity by less than 10% overall.

2) If Yukon-Taiya and Porcupine, Peel/Rat diversion projects are included in Group 1 the figures increase to 24 projects with aggregate capacity of 9,200 MW and average capacity 380 MW.

The table also gives a summarized assessment of the adequacy of the project studies by listing those factors most requiring revision or updating. It will be noted that study depth and adequacy rate highest for Group 3 and lowest for Group 2.

The level of studies in Group 1 is satisfactory in most respects, but overall adequacy is severely flawed by the failure to consider socio-environmental impacts. Updating of project layouts to conform to modern hydroelectric design practice is also important for this group.

Group 2 studies are generally inadequate for inventory purposes, requiring both greater study depth and upgrading of most study factors.

Group 3 studies are generally adequate but with some minor deficiencies in input data to be filled, and the depth of study of one project to be upgraded.

While sites were given importance and study adequacy ratings in Tables 5-1 and 5-2 by assessing the various factors, it was deemed unwise to rank the sites on this basis as originally intended. The degree of subjective judgement necessary in weighting Importance factors suggested caution in applying a combined rating. Similarly there is danger in accepting a combined Adequacy rating, where a study might be rated satisfactory, with a serious deficiency in one factor cloaked by high ratings in several others.

Accordingly, it is recommended that the separate factor ratings in Tables 5-1 and 5-2 should be examined in light of current circumstances and planning priorities to assess the need for study upgrading and updating.

RECOMMENDATIONS

1. In consideration of the practicality of providing funds for upgrading and updating existing inventory studies, a phased program extending over 5 to 10 years is suggested, giving priority to the more important sites and those most in need of revision and updating. Sites would be studied in the context of obtaining for each river or sub-basin, as far as practical, the optimum use of the water resource.

2. The program would depend on the emphasis placed on long term planning compared with meeting short term power needs.

3. The priority for the long term would be to establish the realistic potential in the Group 1 mega projects taking into account socio-environmental restraints. This could mean a much reduced power potential and there would also be changes in project layouts to conform with modern design practice. Substitution of presently unstudied sites on the Yukon River may be required to conform with current realities.

4. For short to medium term power requirements the suggested program would be based on a continuation of Northern Canada Power Commission's recent program of studying selected sites close to potential load centres in south and central Yukon. Such studies would be to pre-feasibility level and be complemented by socio-environmental studies. The program would extend to upgrading studies for other Group 2 sites to Inventory level with priority for more important sites and those most requiring revision and updating. A search for undiscovered sites is proposed as part of the program.

5. A further recommendation is that future studies by different consultants use standard estimating and design criteria, and the reports provide full back up data.

6. Adequate time and funding must be provided for studies, with a program covering fewer selected sites to an adequate level being preferable to a relatively superficial multi-site investigation.

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PART 1

INTRODUCTION AND TERMS OF REFERENCE

1.1 INTRODUCTION AND TERMS OF REFERENCE

The hydroelectric potential of the Yukon Territory has been recognised since early in this century. Small plants were constructed to service the Whitehorse, Dawson and Mayo areas during the first half of the century and shortly thereafter. Commencing in the 1950's efforts were initiated to take stock of the potential developments in a systematic manner.

From field work carried out between 1957 and 1961 the Water Resources Branch of the Department of Northern Affairs and National Resources examined a development plan to utilize the full potential of the main stem of the Yukon River, with substantial projects also on its main tributaries. Furthermore, a reconnaissance survey was made to identify minor projects within the basin.

The report covering these studies was completed in December 1962 and is titled "Yukon River Basin Report". It embodied very substantial field investigations, drawing extensively on a series of geological investigations carried out by Mr. E.B. Owen of the Geological Survey of Canada who ultimately examined some 45 sites in Yukon.

In 1965, subsequent to these significant studies, an investigation to similar level was carried out for the Peel and Porcupine Rivers, two northern river basins not covered in the earlier studies. The Yukon-Taiya and Yukon-Taku diversion schemes, utilizing water from the Upper Yukon River basin, were also examined in a report completed in 1966.

In the next ten years a patchwork of studies were carried out by different consultants, covering various areas and sites to different levels of investigation. Virtually all of these were to a lesser level of study than the earlier Water Resources Branch studies. One exception was the investigation for the Aishihik Project, which proceeded to full feasibility level and finally to construction.

In 1980, adequate funding was obtained to allow investigation to prefeasibility level of some of the more promising sites in areas near potential load centres, and by 1982 seven sites had been investigated to prefeasibility level, together with a mini-hydro scheme on Squanga Creek. A further site, Slate Rapids on the upper Pelly River, was investigated to inventory level in 1983. A full feasibility study was carried out on the Whitehorse Rapids No. 4 unit prior to start of construction in 1981.

This latter group of studies provided some perspective from which to assess the reliability of the previous investigations, which comprised the only hydroelectric inventory available. It was found that this inventory had not included attractive sites now identified. Furthermore, some sites discarded as unpromising in reconnaissance level studies were now found to be attractive. These, together with other indications, suggested that the results of reconnaissance or lower level studies should be treated with great caution. It was clear that they could in some cases provide misleading indications affecting the choice of sites for further investigation.

It was also suspected that the older studies based on twenty year old hydrological, topographic, design, and cost data and criteria, should be revised and updated so that there could be confidence in study findings. Furthermore, since socio-environmental factors had not been considered in most of these earlier studies, it was clear that some reduction in the full potential outlined was now likely. This could result in the need to discard previously favoured sites, replacing them with other sites, some possibly not yet identified.

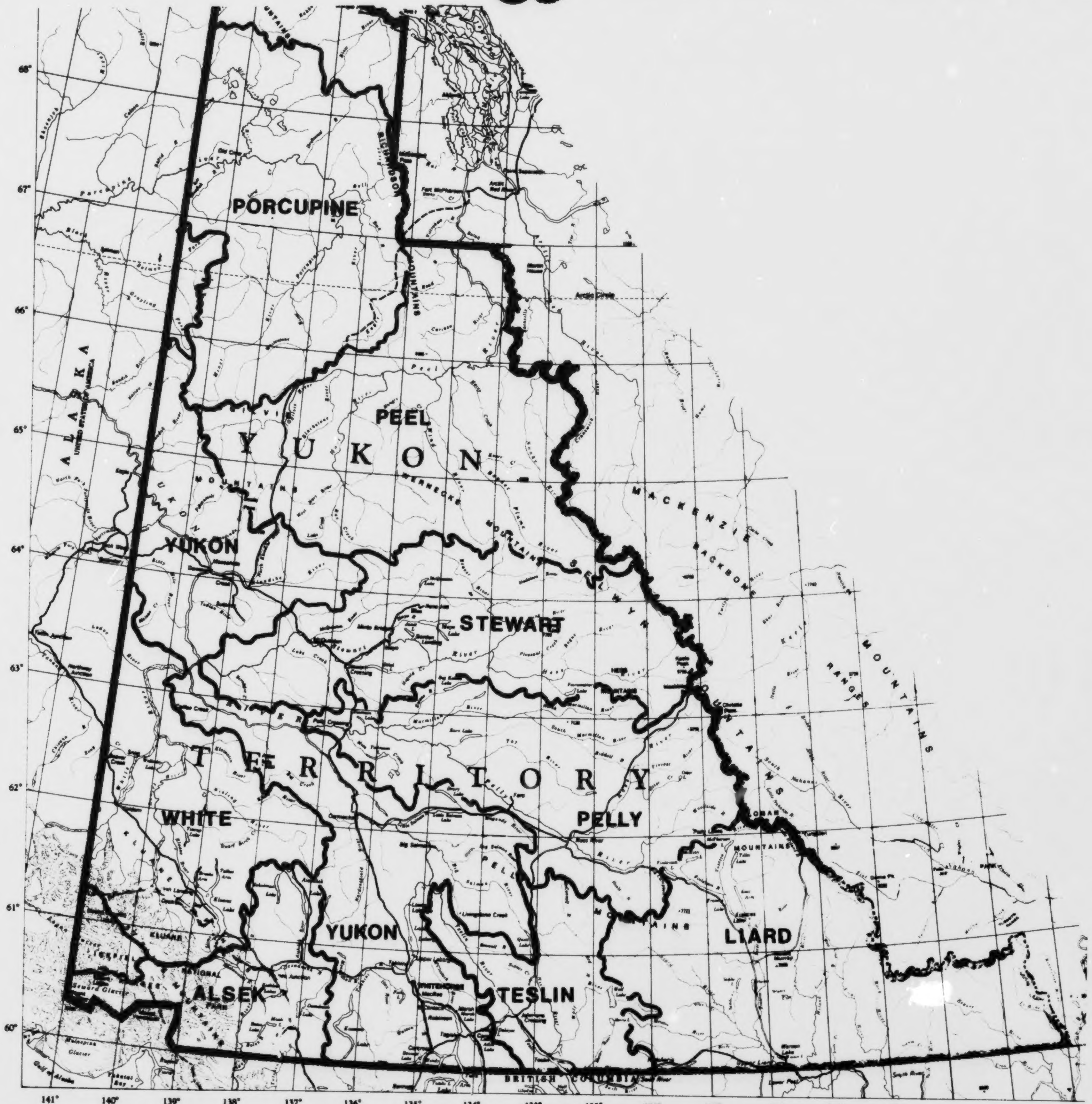
Considering the importance of a reliable hydroelectric inventory to proper planning in the Yukon River Basin, it was seen essential that the current Yukon River Basin Study should include a review of the state of this inventory, with recommendations for upgrading and updating. Accordingly, it was proposed that Northern Canada Power Commission, as the sponsoring agency, arrange such an assignment.

In January 1983, Monenco Consultants Pacific Limited was awarded a contract for this work with a budget of $45,000, and commenced work based on the Terms of Reference, Purpose and Scope of Work included with this report as Appendix A. In summary, the study was to assess the adequacy of the hydroelectric inventory of the Yukon River Basin in Canada and within the remainder of the Yukon Territory. This assessment was to include consideration of such factors as changed dam technology, relative construction costs, up-to-date hydrometric and topographic data, and socio-environmental considerations. A review of the previous investigations available was required in order to assess the input data utilised, and the adequacy of the resulting studies for inventory purposes.

A ranking of sites was to be produced, with evaluation of their potential importance as part of the total resource and also the relative need for early updating and upgrading of existing studies.

Some deviation from the original scope of work has been made to direct the Review to the most valuable areas of investigation. For example, it has been found that the input data and depth of many studies is not adequate to make a satisfactory assessment of whether updating of design concepts and relative costs of construction is an important factor in every case. It is believed, however that the intent of the Review has been fully met.

MONENCO CONSULTANTS PACIFIC LTD.


PORCUPINE
PEEL
YUKON
YUKON
STEWART
TERRITORY
WHITE
PELLY
YUKON
LIARD
ALSEK
TESLIN
ALASKA
UNITED STATES OF AMERICA
MACKENZIE
MOUNTAINS
BRITISH COLUMBIA
Arctic Circle
Gulf of Alaska
68°
67°
66°
65°
64°
63°
62°
61°
60°
141°
140°
139°
138°
137°
136°
135°
134°
133°
132°
131°
130°
129°
128°
127°
126°
125°
124°

LEGEND:

〰 WATERSHED BOUNDARY

BASE MAP REPRODUCED FROM MAP MCR 47, THIRD EDITION,
BY THE DEPARTMENT OF ENERGY, MINES AND RESOURCES.

Kilometres 20 0 20 40 60 80 100 120 140 160 180 200 Km

PLATE 1–1

NORTHERN CANADA POWER COMMISSION

YUKON HYDROELECTRIC
INVENTORY REVIEW

MAJOR RIVER BASINS

PART 2

THE HYDROELECTRIC RESOURCE

2.1 THE HYDROELECTRIC RESOURCE

The total hydro potential of the Yukon Territory has been estimated at about 11,000 MW installed capacity[1], assuming a 60% capacity factor[2]. This potential does not include diversion schemes from the Yukon River Basin such as the Yukon-Taiya, Yukon-Taku or Porcupine/Rat River developments, which, while reducing the power available on the respective main stems, could increase the total generating capacity of the Basin by as much as 2,500 MW. On the other hand, since socio-environmental constraints were not examined for most of these projects, it can be assumed that the full potential could not be achieved either with the diversion schemes or without them.

The geographical distribution of the identified potential, as derived from existing studies, is approximately as indicated on the following page. The installed capacities have been adjusted to a 60% firm capacity factor for uniformity. Yukon River Basin sites in British Columbia are not included nor are some Yukon sites for which, like the B.C. sites, inadequate study information is available. These sites are listed in Part 4, Table 4-3.

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[1] Ref. ....Energy Resources of Northern Canada - HYDRO W.J. Smith Nov. 1976. A copy of the paper is reproduced herein in Appendix B.

[2] Capacity factor here is defined as the proportion of the installed capacity which can generate continuously even under the most adverse flow conditions.

Area	Installed Capacity
- Northern Yukon	1100 MW
- Yukon River main stem	5500 MW
- Major Yukon tributaries: Pelly; Stewart; and Teslin	2200 MW
- Liard Basin in Yukon	550 MW
- Alsek Basin in Yukon	500 MW
- Yukon River Basin in B.C.	150 MW
- Other sites in South and Central Yukon	400 MW

The inventory represented by these aggregate figures comprises some 70 projects ranging from 5 MW to greater than 1,000 MW. A listing of the projects and their major characteristics is presented in Table 2-1, located at the end of this part of the report. The locations of the sites are shown on Plate 2-1 and Plate 2-2. It should be noted that some projects are eliminated if competing projects are developed, and hence the installed capacities listed in Table 2-1 cannot be added together to determine the total hydro potential.

While preliminary estimates have been prepared for most of these potential projects, it is felt that considering the changes in relative construction costs, interest rates, price indices, design criteria and the different approaches of the various agencies and consultants, it would likely be misleading to make cost comparisons from this patchwork of studies. However, reference can be made to Plate 2-3 showing the appropriate STATCAN price indices. These provide some basis for comparing past estimates with 1982 and 1983 price levels, although they must be viewed with caution since they do not seem to reflect past experience with northern development costs.

Of interest is Plate 2-4 which illustrates the normal trend of lower cost per installed kilowatt noted with higher capacity plants. This trend results from the relatively fixed charges of dam, spillway, diversion, etc. which are spread over a larger capacity on major developments. The data for this figure was taken from Table 4-2, being projects for which preliminary estimates are available, and can be considered reasonably reliable. For comparison, the Aishihik and Whitehorse # 4 extension are included. Whether a site is more or less costly than average is indicated by whether the point for that site is above or below the curve.

It should be noted when interpreting from this curve that plant extensions such as Whitehorse #4, Mid-Yukon III, or High Granite II, when considered as separate projects, have points falling well below the curve. This results in part because the cost of dam, spillway, diversion, etc., have been borne by the initial stage of the development which in turn shows a high cost per kW installed. The full developments with all stages should and do lie closer to the curve.

Peaking plants, or those with high installed capacity relative to dependable flow such as Aishihik also tend to have a relatively lower cost/installed kW, because capital cost is spread over more installed kilowatts. At the standard 60% capacity factor used in most recent studies the Aishihik point would move up closer to the Hoole Canyon position.

With these qualifications, a similar curve can provide a better indication of the relative economic attractiveness of projects than simply a direct cost/kW comparison irrespective of plant size. It could be plotted for all sites in the inventory when studies are revised on a comparable basis.

TABLE 2-1

Data for Potential Hydro Projects Identified (II)

Basin	River	Project	Report(10)	Installed Capacity(5) (MW)	Capacity Factor(3) (%)	Net Head (m)	Firm Flow (m^3/s)	Capital Cost(8) ($\$x10^6$)	Price Level	Reservoir Clearing Included?	Socio-environmental Factors Reviewed
Alsek	Tatshenshini	Tatshenshini(I-II)	SI 75	160	60	175(1)	77	145(6)	1973	Yes	Yes
	Bates	Bates Canyon	SI 75	110	60	335(1)	24	98(6)	1973	Yes	Yes
Liard	Liard	Liard Canyon	LB 70	119	60	41	178(7)	60	ca 1969	Yes	No
	Liard	Liard Canyon	SI 75	90	60	47(1)	144(7)	103(6)	1973	Yes	Yes
	Frances	Upper Canyon	UC 69	58	60	37	113	25	1969	No	No
	Frances	False Canyon	FC 82	58	60	45(1)	93(7)	252	1982	Yes	No
	Frances	Lower Canyon	LB 70	56	60	26	146(7)	22	ca 1969	Yes	No
	Frances	Lower Canyon	SI 75	75	60	43(1)	116(7)	60(6)	1973	Yes	Yes
	Hyland	Hyland Diversion	LB 70	Diversion	-	-	61(2)	24	ca 1969	Yes	No
	Beaver	Saucy Creek	LB 70	46	60	43	71	31	ca 1969	Yes	No
	Beaver	Beaver Crow	LB 70	82	60	75	74	?	ca 1969	Yes	No
	Beaver	Fantasque	LB 70	78	60	75	71	59	ca 1969	Yes	No
	Coal	Quartz Creek	LB 70	38	60	79	33	?	ca 1969	Yes	No
Peel	Peel	Aberdeen Falls	PP 65	448	65	108	204	205	1964	?	No
	Peel	Aberdeen Falls	SI 75	300	60	120(1)	176	263(6)	1973	Yes	Yes
	Peel	Bonnet Plume	PP 65	198	65	70	204	86	1964	?	No
	Peel	Peel Diversion	PP 65	755	65	-	204	450	1964	?	No
Pelly	Pelly	Detour Canyon	YB 62	Storage	-	-	?	43	1961	Yes	No
	Pelly	Detour Canyon	SI 75	100	60	55(1)	136	124(6)	1973	Yes	Yes
	Pelly	Low Granite Canyon (I-II)	GC 80	120	60	40(1)		305	1980	Yes	Yes
	Pelly	High Granite Canyon (III)	GC 82	254+	77	62		469	Dec 1981	No	No
	Pelly	Braden's Canyon	YB 62	180	75	52	?	63	1961	Yes	No
	Pelly	Braden's Canyon	SI 75	150	60	30(1)	326	95(6)	1973	Yes	Yes
	Pelly	Hoole Canyon	HC 82	40	60	45(1)	64	146	1982	Yes	Yes
	Pelly	Slate Rapids	SR 83	42	60	64	45	165	Dec 1981	Yes	No
	Anvil	Anvil Creek	CY 68	10	60	175	4	13	ca 1968	Yes	No
	Tay	Tay	CY 68	31	60	81	27	43	ca 1968	Yes	No
	Earn	Earn	CY 68	7	60	61	8	14	ca 1968	Yes	No
	Ross	Ross Canyon	RC 82	30	60	51(1)	43	181	1982	Yes	No
	Ross	Prevost Canyon	RP 62	12	50	20	25	10	1961	No	No
	Ross	Prevost Canyon	PS 66	8	75	26	24	9	ca 1966	No	No
	Ross	Prevost Canyon	CY 68	12	60	32	24	15	ca 1968	Yes	No
	Mica	Mica Creek	CY 68	10	60	82	8	16	ca 1968	Yes	No

TABLE 2-1 (Cont'd)

Basin	River	Project	Report(10)	Installed Capacity(5) (MW)	Capacity Factor(3) (%)	Net Head (m)	Firm Flow (m^3/s)	Capital Cost(8) ($\$\times10^6$)	Price Level	Reservoir Clearing Included?	Socio-environmental Factors Reviewed
Porcupine	Porcupine	Bell	PP 65	110	65	40	201	82	1964	?	No
	Porcupine	Bell	SI 75	110	60	44(1)	184	126(6)	1973	Yes	Yes
	Porcupine	Porcupine Canyon	PP 65	190	65	42	292	97	1964	?	No
	Porcupine	Porcupine Diversion	PP 65	1241	65	-	295	546	1964	?	No
Stewart	Stewart	Fraser Falls (I-II)	YB 62	347	75	69	?	115	1961	Yes	No
	Stewart	Fraser Falls	SI 75	300	60	79(1)	283	244(6)	1973	Yes	Yes
	Stewart	Independence	YB 62	431	75	80	?	212	1961	Yes	No
	Stewart	Independence	SI 75	450	60	81(1)	396	375(6)	1973	Yes	Yes
	Stewart	Porcupine	YB 62	223	75	30	?	88	1961	Yes	No
	Stewart	Porcupine	CY 68	83	60	?	172	-	-	-	No
	Stewart	Seven Mile Canyon	CY 68	10	60	?	25	16	ca 1968	Yes	No
	Stewart	Big Kalzas Lake	CY 68	17	60	268	5	27	ca 1968	Yes	No
	Hess	Two Mile Canyon	CY 68	53	60	?	59	48	ca 1968	Yes	No
	Hess	Hess Canyon	CY 68	18	60	?	34	29	ca 1968	Yes	No
	Hess	Rogue	CY 68	12	60	?	15	34	ca 1968	Yes	
	Pleasant	Pleasant Creek	CY 68	5	60	?	7	16	ca 1968	Yes	No
	Ethel	Ethel Lake Diversion	CY 68	8	60	290	2	8	ca 1968	Yes	No
	Mayo	Mayo B	CY 68	9	60	30	20	8	ca 1968	Yes	No
	Lake	Lake Creek Diversion	CY 68	13	60	?	5	19	ca 1968	Yes	No
	McQuesten	North McQuesten	CY 68	5	60	46	8	19	ca 1968	Yes	No
White	White	Upper Canyon	YB 62	?	-	?	?	?	-	-	-
	White	Upper Canyon	CY 68	16	60	?	18	25	ca 1968	Yes	No
	White	Lower Canyon	YB 62	?	-	?	?	?	-	-	-
	White	Lower Canyon	CY 68	16	60	?	20	42	ca 1968	Yes	No
	Kluane	Kluane Canyon	KL 62	17	50	11	70	11	1961	No	No
	Kluane	Kluane Canyon	CY 68	12	60	?	75	10	ca 1968	Yes	No
	Donjek	Donjek	CY 68	43	60	58	52	158	ca 1968	Yes	No
Lower Yukon	Sixty Mile	Sixty Mile Diversion	CY 68	18	60	?	9	32	1968?	Yes	No
	Forty Mile	Forty Mile	CY 68	16	60	?	22	18	1968?	Yes	No
	Fifteen Mile	Fifteen Mile Diversion	CY 68	7	60	?	6	16	1968?	Yes	No
	Indian	Indian	CY 68	6	60	?	11	16	1968?	Yes	No

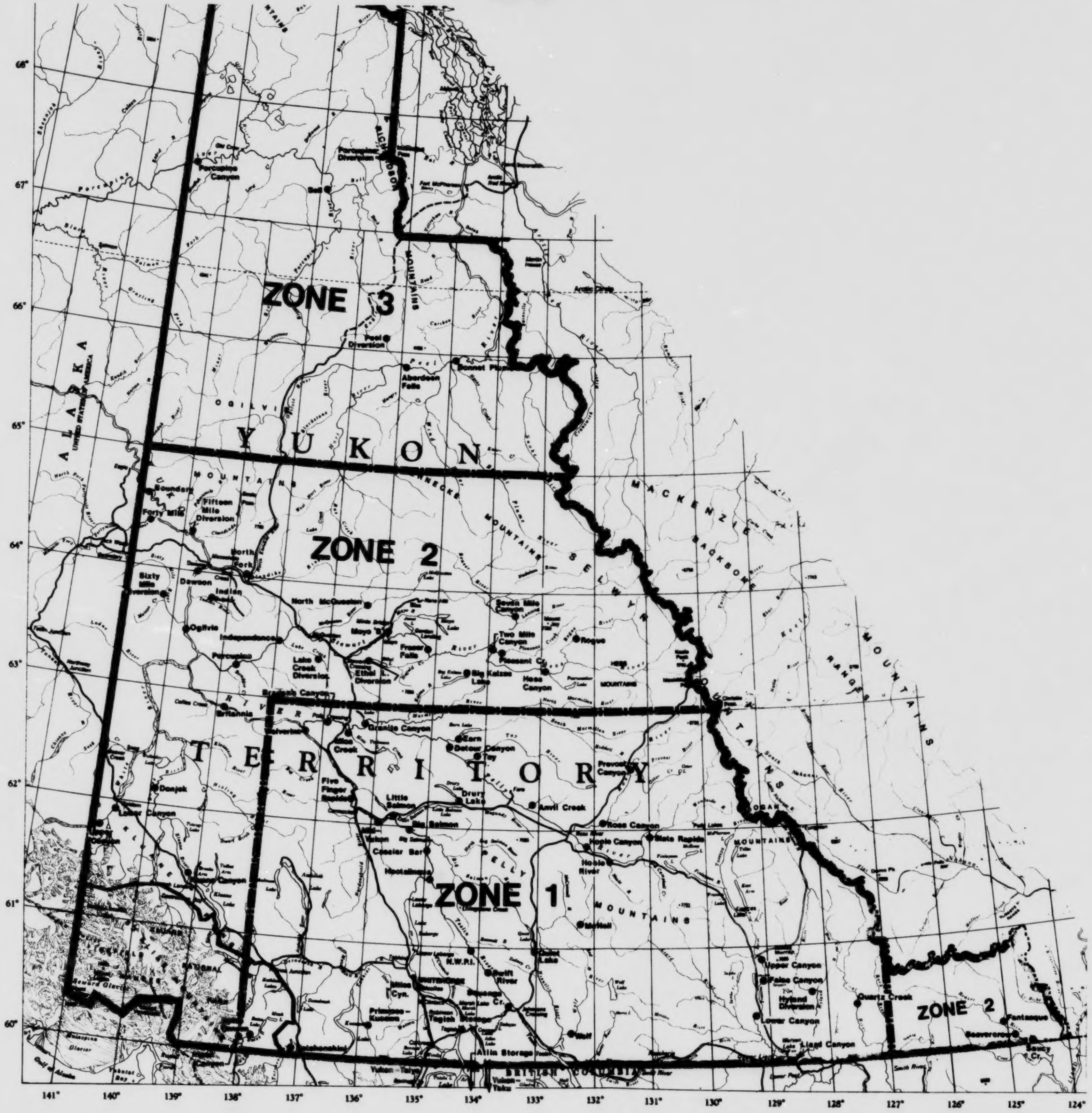
TABLE 2-1 (Cont'd)

Basin	River	Project	Report(10)	Installed Capacity(5) (MW)	Capacity Factor(3) (%)	Net Head (m)	Firm Flow (m^3/s)	Capital Cost(8) ($\$ \times 10^6$)	Price Level	Reservoir Clearing Included?	Socio-environmental Factors Reviewed
Yukon	Yukon	Miles Canyon	YB 62	Storage	-	-	?	45	1961	Yes	No
	Yukon	Hootalinqua	YB 62	259	75	35	?	103	1961	Yes	No
	Yukon	Big Salmon	YB 62	301	75	38	?	111	1961	Yes	No
	Yukon	Mid-Yukon (I/II)	MY 80	240	59	86(1)	225	414	1980	No	Yes
	Yukon	Mid-Yukon (III)	MY 80	240	66	86(1)	456	231	1980	No	Yes
	Yukon	High Five Finger Rapids	YB 62	455	75	56	?	124	1961	Yes	No
	Yukon	Low Five Finger Rapids	SI 75	75	60	24(1)	212	167(6)	1973	Yes	Yes
	Yukon	Wolverine	YB 62	476	75	59	?	160	1961	Yes	No
	Yukon	Britannia	YB 62	459	75	46	?	147	1961	Yes	No
	Yukon	Ogilvie	YB 62	896	75	44	?	267	1961	Yes	No
	Yukon	Dawson	YB 62	571	75	27	?	163	1961	Yes	No
	Yukon	Boundary	YB 62	1006	75	49	?	235	1961	Yes	No
	Yukon	Yukon-Talya (I-III)	YT 66	4050	85	563	595	1071	1964/65	Yes	No
	Yukon	Yukon-Taku (I-VI)	YT 66	3692	85	505	606	1284	1964/65	Yes	No
	Atlin	Atlin Storage (4)	AT 80	Storage	-	-	-	3	1979	No	Yes
	Yukon	Tagish Storage	Unpublished	Storage	-	-	112	2	1973	No	No
	Teslin	NWPI (9)	TR 80	55	60	27(1)	180	236	1980	Yes	
	Teslin	Swift	YB 62	158	75	36	?	102	1961	Yes	No
	Wolf	Wolf	CY 68	13	60	88	10	25	1968?	Yes	No
	McNeil	McNeil	CY 68	10	60	73	9	13	1968?	Yes	No
	Big Salmon	Quiet Lake/Nisutlin	CY 68	15	60	46	18	28	1968?	Yes	No
	Takhini	Primrose	CY 68	19	60	259	5	16	1968?	Yes	No
	Takhini	Primrose	SI 75	30	60	192(1)	11	39(6)	1973	Yes	Yes
	Takhini	Kusawa	YB 62	17		15					
	Little Salmon	Little Salmon	MH 80	15	60	44	24	>97	1980	Yes	No
	Little Salmon	Drury Lake	CY 68	4	60	107	3	5	1968?	Yes	No

Notes:

(1) Gross head
(2) With storage at False Canyon
(3) Load Factor for all projects in YB62, YT65, KL62, PP65, RP62 and PS66
(4) Site in northern British Columbia
(5) Maximum development with upstream storage
(6) Interest during construction not included
(7) Not including Hyland Diversion flow
(8) Capital costs are given in current $ for Price level year
(9) North West Power Industries site
(10) For key to report reference see part 4 p.4-5
(11) For other sites not reviewed see Part 4 Table 4-3 and Table 4-2 (Surprise Lake)

MONENCO CONSULTANTS PACIFIC LTD.


ZONE 3
ZONE 2
ZONE 1
ZONE 2
YUKON
TERRITORY
ALASKA
UNITED STATES OF AMERICA
BRITISH COLUMBIA
OGILVIE
MOUNTAINS
MACKENZIE
SELWYN
MOUNTAINS
PELLY
MOUNTAINS
Arctic Circle
Porcupine Canyon
Porcupine Diversion
Bell
Peel Diversion
Aberdeen Falls
Bonnet Plume
Boundary
Forty Mile
Fifteen Mile Diversion
North Fork
Sixty Mile Diversion
Dawson
Indian
North McQuesten
Ogilvie
Independence
Porcupine
Mayo "B"
Fraser Falls
Lake Creek Diversion
Ethel L. Diversion
Seven Mile Canyon
Two Mile Canyon
Pleasant Cr.
Rogue
Big Kalzas Lake
Hess Canyon
Bradens Canyon
Britannia
Granite Canyon
Earn
Detour Canyon
Tay
Prevost Canyon
Five Finger Rapids
Little Salmon
Drury Lake
Anvil Creek
Big Salmon
Ross Canyon
Hoole Canyon
Slate Rapids
Hoole River
Cassiar Bar
Hootalinqua
N.W.P.I.
Swift River
Atlin Cyn.
Primrose-Kusawa
Tagish Storage
Atlin Storage
Yukon-Taiya
Yukon-Taku
Wolf
Upper Canyon
False Canyon
Hyland Diversion
Lower Canyon
Liard Canyon
Quartz Creek
Fantasque
Beavercrow
Saucy Cr.
68°
67°
66°
65°
64°
63°
62°
61°
60°
141°
140°
139°
138°
137°
136°
135°
134°
133°
132°
131°
130°
129°
128°
127°
126°
125°
124°

LEGEND:

● POTENTIAL HYDRO PROJECTS.

ZONE 1 — LOCATION ZONES USED IN RATING PROJECT IMPORTANCE (see Section 5.3 of Text)

BASE MAP REPRODUCED FROM MAP MCR 47, THIRD EDITION, BY THE DEPARTMENT OF ENERGY, MINES AND RESOURCES.

Kilometres 20 0 20 40 60 80 100 120 140 160 180 200 Km

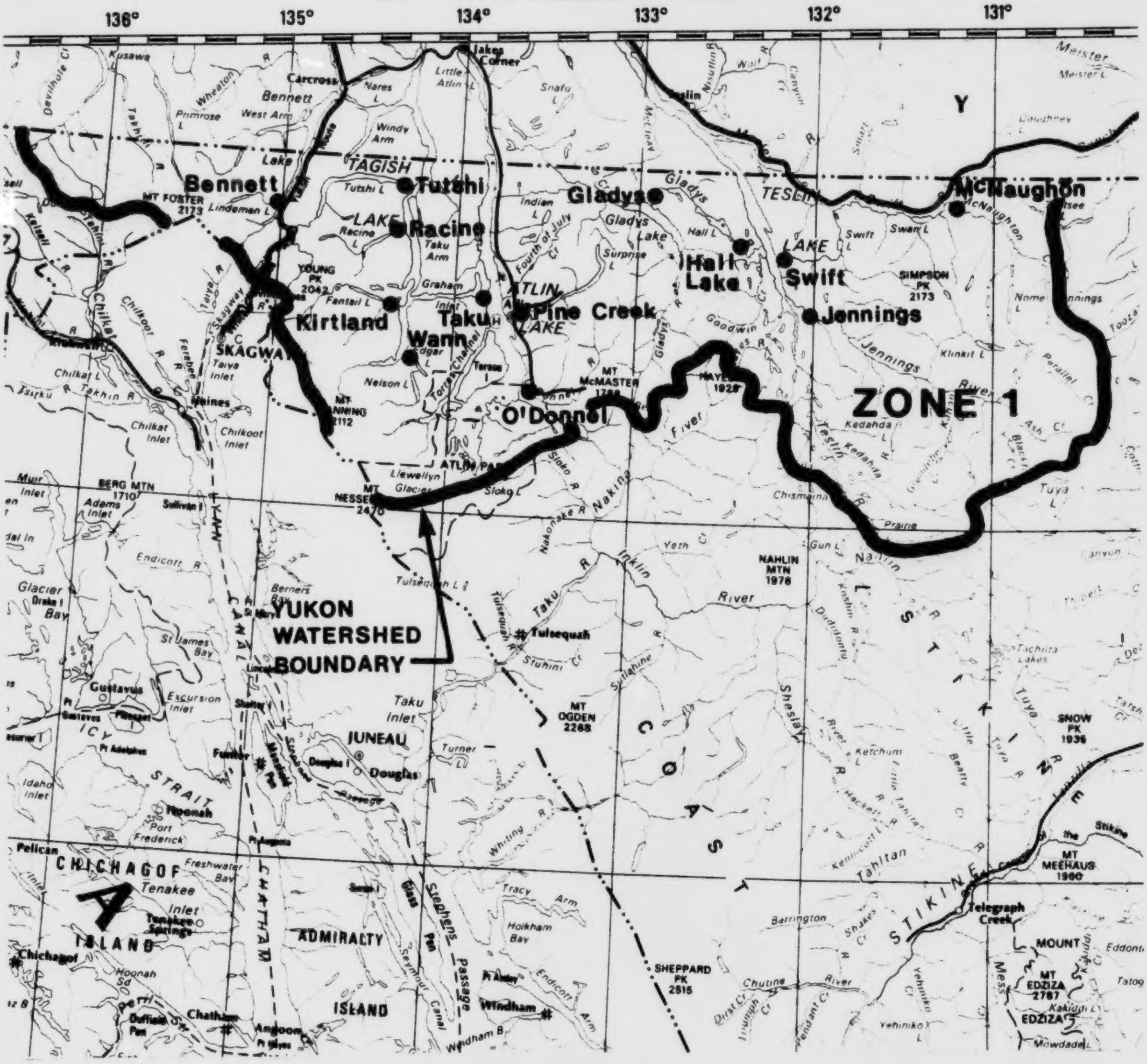
PLATE 2-1

NORTHERN CANADA POWER COMMISSION

YUKON HYDROELECTRIC
INVENTORY REVIEW

POTENTIAL SITES

MONENCO CONSULTANTS PACIFIC LTD.



136°
135°
134°
133°
132°
131°
Bennett
Tutshi
Racine
Kirtland
Taku
Wann
Pine Creek
Gladys
Hall Lake
Swift
Jennings
McNaughon
O'Donnel
ZONE 1
YUKON WATERSHED BOUNDARY
SKAGWAY
JUNEAU
Douglas
Carcross
Atlin
TAGISH LAKE
TESLIN LAKE
ATLIN LAKE
CHICHAGOF ISLAND
ADMIRALTY ISLAND
A
STIKINE
COAST
Telegraph Creek
Tulsequah
Y

20 0 20 40 60 80 100 Km

Kilometres

PLATE 2-2

NORTHERN CANADA POWER COMMISSION

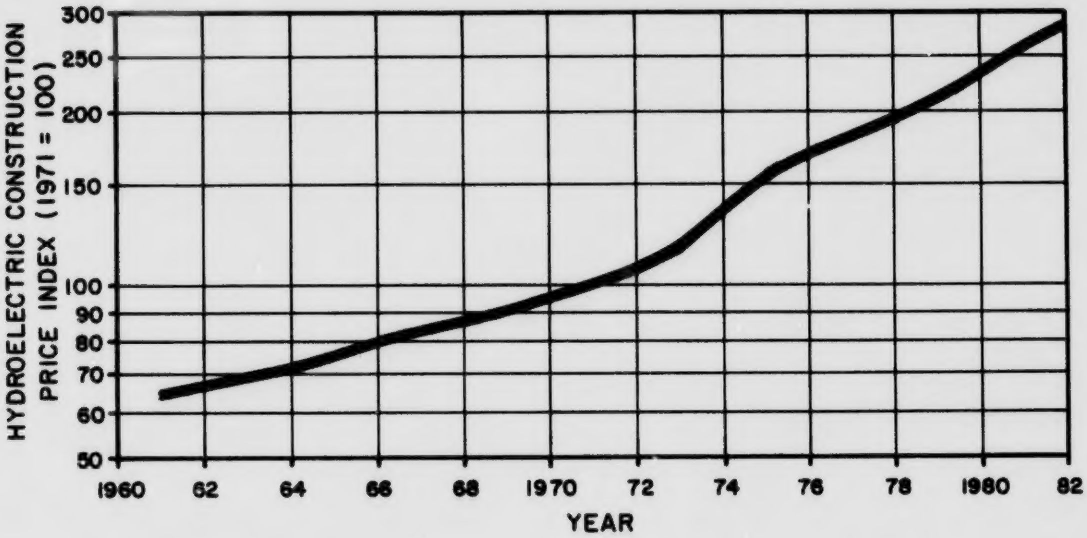
YUKON HYDROELECTRIC
INVENTORY REVIEW

POTENTIAL SITES
IN BRITISH COLUMBIA

LEGEND

● POTENTIAL HYDRO PROJECTS

BASE MAP REPRODUCED FROM MAP 1J,
BY THE B.C. SURVEYS AND MAPPING BRANCH



YEAR	0	1	2	3	4	5	6	7	8	9
1960 - 69	—	64.4	66.2	68.4	70.6	74.1	78.7	81.5	84.9	89.7
1970 - 79	95.6	100.0	106.3	116.1	137.9	157.6	171.6	181.8	195.8	212.9
1980 - 89	234.2	265.7	286.4							

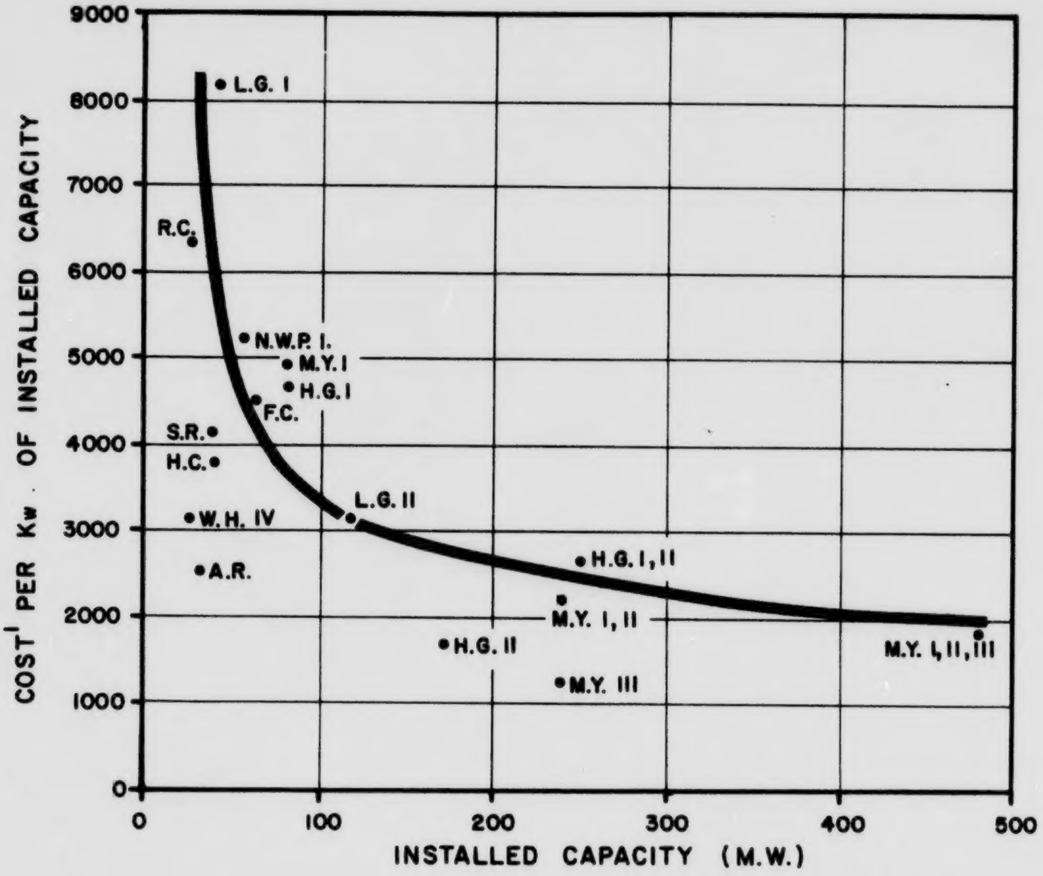
REF: STATISTICS CANADA
PRICE INDEX NO. D462201

PLATE 2-3

NORTHERN CANADA POWER COMMISSION

YUKON HYDROELECTRIC
INVENTORY REVIEW

CONSTRUCTION PRICE INDEX FOR
HYDROELECTRIC GENERATING STATIONS
(1961 - 1982)



LEGEND

DESIGNATION	PROJECT
L.G. I	LOW GRANITE CANYON – STAGE I
L.G. II	LOW GRANITE CANYON – STAGE II
H.G. I	HIGH GRANITE CANYON – STAGE I
H.G. II	HIGH GRANITE CANYON – STAGE II
H.G. I, II	HIGH GRANITE CANYON – STAGE I, II
M.Y. I	MID – YUKON – STAGE I
M.Y. I, II, III	MID – YUKON – STAGE I, II, III
M.Y. III	MID – YUKON – STAGE III
N.W.P. I.	N.W.P. I.
S.R.	SLATE RAPIDS
H.C.	HOOLE CANYON
F.C.	FALSE CANYON
W.H. IV	WHITEHORSE – STAGE IV
A.R.	AISHIHIK
R.C.	ROSS CANYON

NOTES

1 1982 $ INCLUDING CLEARING

2 ESTIMATED COSTS AND CAPACITIES FROM RECENT STUDIES

PLATE 2-4

NORTHERN CANADA POWER COMMISSION

YUKON HYDROELECTRIC
INVENTORY REVIEW

COST/K.W. vs SIZE OF INSTALLED HYDRO PLANT

PART 3

THE IMPORTANCE OF AN ADEQUATE AND RELIABLE HYDROELECTRIC INVENTORY

3.1 THE IMPORTANCE OF AN ADEQUATE AND RELIABLE HYDROELECTRIC INVENTORY

311 INVENTORY ADEQUACY

The need to know the magnitude, location and quality of a resource for planning optimum benefit to society is self evident. This is particularly the case with potential hydro projects which must be identified, assessed for power potential, and compared with alternative sites and energy sources, taking into account both the capital cost and any socio-environmental factors. However, while it is widely accepted that the search for and development of non-renewable resources such as oil and minerals requires costly exploration including drilling, the realisation is often lacking that this also applies to the hydro resource. As a result, some studies are carried out to a rather superficial level due to provision of inadequate time and budget. Such studies may well remain the only appraisal of the sites available for many years, and must be used for planning. Any shortcomings resulting from inadequate input data and study will not become apparent until new and more searching investigations are carried out.

Besides the need for a reliable inventory for planning, there can be the more immediate necessity of choosing the next project to meet a new load of previously unknown location and magnitude. In order to avoid the delay inherent in commencing at that time a search for a suitable site, there should be at hand a selection of projects of various sizes and at various locations, which have been studied to a sufficient depth that a proper choice for feasibility studies can be made.

In recent years it has been necessary to obtain regulatory approval for each new hydro project, in order to ensure that the proposed development has been properly selected as optimum for society's needs with regard to economic viability, safety, and social and environmental concerns. This has emphasized the requirement of proper inventory information to permit correct selection, and added the need for socio-environmental appraisal. It has also increased the lead time for a project to progress from commencement of investigations to final commissioning, to between 5 and 10 years.

In Yukon the need for a new hydro plant normally results from a new mine or extension to an existing mine and mill. In future this state of affairs will likely continue but with the added possibility of a smelter or other major industrial load. In many or most cases, these industrial projects can be brought to completion in less time than the hydro plant lead time. The necessity of starting hydro investigation for the new load from an adequate inventory is quite clear, so that much needed industrial development is not discouraged by uncertainty and delay re power supply and power costs.

The foregoing states the main reasons for an adequate hydro inventory, which might be described as the essential tool needed to allow development of the resource in an orderly, optimum, and timely manner to meet the needs of the northern society. There are other uses of the inventory less easily anticipated. Recently there arose the need at short notice for potential project priorisation and development data for all proposed hydro plants to aid land selection for the current Indian land claims negotiations. Another use for project water level data is in flood plain and land use planning and management.

With acceptance of the need for an adequate inventory, the cost must be addressed. It is clear that it is not practical to bring all sites up to an adequate level in one study. Instead, a phased program must be arranged with the most important and least studied sites receiving priority treatment.

Where up to 100 potential sites are involved, spread over such a great area as Yukon with such a small population, the need to get the most from every investigation dollar is crucial. It is essential to select only the most promising sites for expensive detailed studies. This can normally be done from inventory level investigations of all available sites with preliminary capital cost estimates for comparison purposes. "Inventory" level is taken to be the least detailed and costly standard of study which will permit confident selection of sites for pre-feasibility and further investigations. The "hierarchy" of studies is explained below with the place of the Inventory level study identified relative to the other levels.

312 LEVELS OF STUDY

For the purpose of this Review the following levels of study are used and the probable range of costs per project studied are given.

- Category A - Pre-reconnaissance	$ 5,000 - $ 25,000
- Category B - Reconnaissance	
- Category C - Inventory	$ 25,000 - $ 150,000
- Category D - Pre-feasibility 1	$200,000 - $ 500,000
- Category E - Pre-feasibility 2	
- Category F - Feasibility	$2,000,000 - $5,000,000

At these costs the desirability of avoiding premature or unnecessary pre-feasibility and feasibility studies can readily be appreciated, and each level of study is aimed at reducing the number of sites which require further study at that time. The advantages of a screening process using successively more detailed studies is apparent.

Since the different levels of study have been given many different names, the following definitions are given below to describe their use in this review.

Category A - Pre-reconnaissance

A purely office study with no field work utilizing existing mapping, flow records, aerial photographs and reports to indicate possible sites in the study area and, where possible, their power potential.

Category B - Reconnaissance

This level of investigation includes at least one reconnaissance visit to each of the sites. The office studies, including hydrology proceed somewhat further to permit elimination of sites which are not technically possible, and so aids in selection of sites for inventory level studies. A "guesstimate" of cost may be made.

Category C - Inventory

At least two days to two weeks of field work is required including barometer or ground levelling to establish key elevations. Site topography from existing aerial photographs is normally needed. Geotechnical appraisal is carried out, including minimum sub-surface exploration, sometimes by seismic methods. Hydrological studies are carried out to determine mean and flood flows, storage, and firm flow available.

A general layout and sections and elevations are expected to illustrate the basic design. A preliminary estimate of capital cost is made. Selection of favoured sites for pre-feasibility studies is made possible at this study level.

Category D and E - Pre-feasibility Level

One season of field investigation is normal, with drilling to probe foundation conditions. Photo interpretation of surficial geology is carried out in conjunction with a construction materials search. Topographic mapping for structures and for the reservoir may be required, often with new low level aerial photography. Detailed hydrological studies define firm and flood flows with some accuracy.

Project design includes preliminary optimisation, and a set of conceptual drawings.

A detailed estimate is produced with quantities and a construction schedule.

Category E indicates more field work, including drilling and materials search, than Category D.

This level of study must provide a confident recommendation for the selected site to be studied to full feasibility level provided the concurrent socio-environmental study shows acceptability.

Category F - Feasibility Level

Full investigation by a program of about two years duration, including detailed sub-surface evaluation by drill holes and test pits. A comprehensive materials search is required, with field work necessary to confirm adequate quantities. Complete conceptual design and optimization is required with a definitive capital cost estimate on which a decision whether to proceed with the project can be made.

In addition to these various studies, there are often pre-contract investigations, but these usually occur after the decision to proceed with the project has been made and often depend on the type of contract to be let.

The varying amounts of work involved from site to site can be understood by comparing two extremes.

Case A is a storage/power site with bare, competent bedrock exposed right across the river bed and up both abutments. Large quantities of gravel are visible in river cut terraces and the outcropping rock is suitable for rip rap. The site has been mapped with suitable contour intervals in a previous study and 1:50,000 NTS maps are available for the reservoir. There is a 40 year period of record over which river flow readings are available. This site will require little drilling, a relatively modest field program, and uncomplicated hydrological studies.

In Case B, all contrary conditions exist: deep bedrock not exposed in outcrops, there is deep overburden of unknown quality for foundations, there are no visible sources of construction materials, only 1:250,000 mapping is available with 500' contours, and there are no flow measurement records on the river. A separate storage dam upstream is required with side dams. Such a site will require much drilling and extensive field and office studies.

313 OPTIMUM RIVER DEVELOPMENT

Where there are several potential projects on a river, it is not normally sufficient to examine each in isolation from the others. The head which can be developed may be limited by the need to avoid flooding out an adjacent upstream project. Furthermore flow regulation from an upstream site affects the potential of downstream sites. Some studies address these problems and develop an optimum scheme while others do not.

It is suggested that depending on the river and sites involved it is necessary to examine optimum river development at either the Inventory Level C or at the Pre-feasibility Levels D and E. This requirement may dictate higher level studies than would otherwise be needed at apparently unattractive sites adjacent to selected sites.

314 STUDY RELIABILITY

Study adequacy can imply reliability, and the conclusions of a properly adequate study merit acceptance with confidence. Unfortunately there is evidence that for various reasons past studies have given misleading indications for some sites. It is, however, only when sites have later been studied to a greater depth, or where project has actually been constructed, that the earlier conclusions are tested, and so relatively few comparisons are available.

When such comparisons are made for sites originally studied only to Reconnaissance level, changes from the earlier findings are not unexpected. Such studies must be completed with many unknowns in the data, and they are only expected to narrow down the field of sites for Inventory level studies.

There are now about ten sites which have recently been studied, and which can be used to test previous study findings. The results are tabulated on the following page:

Site	Original Finding	Recent Finding	Remarks
Mid Yukon	Site not discovered	One of best mega projects	Suggests many good sites undiscovered
Low Granite	140 MW - attractive	120 MW - a viable site	Original studies verified
High Granite	350 MW - attractive	254 MW or greater - one of best sites	Original studies verified
Teslin NWPI	Selected site - attractive	High capital costs - not favoured	Original findings not confirmed
Atlin Storage	Site not studied	N/A	N/A
Aishihik	7 MW available at 60% CF	20 MW available at 60% CF	More head and flow were utilized
False Canyon	Site rated unpromising	One of the better sites	Another study gave good rating
Ross Canyon	34 MW plant possible	30 MW plant possible	Original studies verified
Hoole Canyon	Selected site 38 MW	One of best sites 40 MW	Original studies verified
Slate Rapids	Site rated unpromising	One of best sites 42 MW	Not studied
Squanga Creek	Site not discovered	Attractive mini hydro	Mini hydro not generally studied

From this table it can be seen that, leaving aside the Atlin and Squanga Creek sites where a comparison between former and recent study results is not possible, out of a total of nine sites compared, only four show agreement between early and recent studies.

Of the remaining five, Mid-Yukon was completely missed in the inventory, and False Canyon and Slate Rapids were dismissed as unpromising in certain earlier studies. These three schemes are now rated amongst the best available. The Aishihik project was estimated at one third its actual potential. The former highly rated NWPI Teslin scheme has been found to be relatively unattractive due to high capital costs.

A similar problem has been noted on one of the very few projects studied to pre-feasibility level in the NWT. The power potential of the Great Bear River was radically underestimated in earlier appraisals (see Appendix B, p 6).

In summary, the indications from half of the Level B Reconnaissance studies, which it has been possible to test against more detailed studies recently carried out, have not been confirmed. Furthermore one of the best projects available on the Yukon River (Mid-Yukon) has been completely missed by early inventory work. Accordingly the need for upgrading much of this work has been established.

PART 4

INVESTIGATIONS OF POTENTIAL HYDROELECTRIC DEVELOPMENTS

(1960 - 1983)

4.1 INTRODUCTION

A large number of hydro power studies have been carried out for the Yukon over the last 20 years or so. These studies have ranged from preliminary identifications and investigations of potential sites along individual rivers or in particular regions; to updates based on more extensive information and data; and ultimately, for few sites, to detailed pre-feasibility studies. Part 7 contains a bibliography of the reports produced by these various studies.

It is the fact that the overall inventory of potential hydro sites is comprised of so many studies which complicates a review of this type. Because the studies were carried out by different organizations, at different times, and using different criteria, it is difficult to assess the relative depth and adequacy of each study and to rate the relative attractiveness of various potential projects.

In this part of the report, those previous studies which are relevant to the inventory review are summarized (see Table 4-1 contained at the end of this Part). These summaries provide the basis for the evaluations contained in Part 5.

4.2 CLASSIFICATION OF PREVIOUS STUDIES

Before evaluating the previous studies, it was necessary to determine which ones were relevant to the inventory review process. It was deemed important not to give misleading indications that a valid review was possible where insufficient input data was available. Avoidance of inappropriate entries in the tabulations was also desired. Accordingly, the reports listed in the Bibliography were classified as relevant or not relevant, based on the criteria described below. It is important to note that this classification applies only to the study, not the sites, and that all potential sites are listed in Table 2-1 (located at the end of Part 2), or Tables 4-2 or 4-3 regardless of the relevance of any of the reports.

421 PREVIOUS STUDIES NOT RELEVANT TO THE INVENTORY REVIEW

Studies were considered not to be relevant to the review if they fell into any one of the following categories:

.1 Existing Plants

Studies concerned with sites at which hydroelectric developments were subsequently constructed were eliminated by virtue of the plants' existence. This included plants at Whitehorse Rapids, Aishihik, and Mayo, and a storage dam at Marsh Lake.

.2 Recent Studies

Since 1980, several feasibility and prefeasibility studies have been carried out on individual sites; including, Granite Canyon, Hoole Canyon, Mid-Yukon, Teslin River (NWPI site), False Canyon, Ross Canyon, Squanga Creek, Atlin Lake, Pine Creek, and Aishihik Diversions. Also, an inventory level study of the Slate Rapids site on the Pelly River was completed. For the purpose of the review it was determinmed that these studies were based on adequate, up-to-date data, and were at least to Inventory Level, Category C. Therefore, they were not specifically included in the review, although they were rated as to the depth of study, and the importance of the sites (see Table 4-2 and Part 5).

.3 Superceded Studies

Detailed reviews were not made of reports on sites which had been superceded by subsequent studies to a higher level. In most cases, this applied only to certain sites in a study, rather than to the entire study.

.4 Mini Hydro

Studies of potential sites having an installed capacity of less than about 5 MW were not considered in the review, since in general "mini hydro" has not yet been investigated and many sites remain to be discovered. However, Drury Lake was included as an exception because of its strategic location. Known mini hydro sites, although not reviewed, are listed in Table 4-3.

.5 Undocumented Sites

Certain of the studies provided little or no documentation on the specific location, size and configuration of some sites. In these cases it was considered that there was insufficient information available to provide a basis for review. Nevertheless, such sites were included in Table 4-3. Once again this situation was limited to individual sites within a study, rather than to the entire study.

British Columbia Hydro and Power Authority have carried out office studies on about 12 sites in the B.C. portion of the Yukon Basin. These are pre-reconnaissance Category A studies listing possible head, annual flow, plant capacity, and energy output. B.C.H.P.A have advised that due to the small size of these projects and their distance from the Yukon grid, none of these sites merit further study unless local loads develop. Site locations are shown on Plate 2-4.

Several of the GSC topical reports investigated sites which were not included in any of the hydroelectric inventory studies. These sites included: Five Finger Rapids Draw Extension, Wolverine Draw, Fort Selkirk, Selwyn, Lower Ogilvie, and Lower Dawson on the Yukon River; Gerc on the Pelly River; Lower Liard Canyon on the Liard River; Five Mile Rapids on the Stewart River; and one of two sites on the Lapie River. Apparently, these sites were eliminated from the inventory studies either because they were considered to be technically less attractive than other nearby sites, or because they did not fit into a scheme to develop the maximum head along a river. This latter point applies mainly to the sites on the Yukon River, which were studied for the 1962 Yukon River Basin Study (YB 62). Some of these sites could take on a renewed significance, now that socio-environmental factors have a greater importance than they did in the early 1960's and might dictate modification of the original site sequence for optimum river development. Therefore, the sites have been included in Table 4-3 although it is considered that there is insufficient documentation on which to base an evaluation.

422 PREVIOUS STUDIES RELEVANT TO THE INVENTORY REVIEW

Previous studies considered relevant to the inventory review comprised those not eliminated through any of the criteria listed above. Specifically, the following reports were evaluated:

Study Designation	Title/Author/Date
KL62	*Interim Report on Hydroelectric Power Possibilities of Kluane River, Yukon Territory: Kluane Canyon Dam Site*. Water Resources Branch, Department of Northern Affairs and National Resources. May 1962.
RP62	*Interim Report on Hydroelectric Power Possibilities of Ross River, Yukon Territory: Prevost Canyon Dam Site; Ross Canyon Damsite.* Ibid. November 1962.
YB62	*Yukon River Basin Report.* Ibid. December 1962.

PP65 *Report on Hydroelectric Power Resources of the Porcupine, Peel, and Rat River Region, Yukon and Northwest Territories.* Ibid. April 1965.

YT66 *A Preliminary Appraisal of the Yukon-Taiya and Yukon-Taku Storage and Power Schemes.* Water Resources Branch, Department of Mines and Technical Surveys. August 1966.

PS66 *Power Supply for the Yukon: A Preliminary Appraisal* and *Addendum to Preliminary Appraisal.* Montreal Engineering Company, Limited. March 1966 and July 1966.

CY68 *Hydroelectric Resources Survey of the Central Yukon Territory.* T. Ingledow & Associates Limited. January 1968.

UC69 *Frances River Development.* Montreal Engineering Company, Limited. December 1969.

LB70 *Power Survey of the Liard River Basin: Yukon and Northwest Territories.* T. Ingledow & Associates Limited. February 1970.

SI75 *The Development of Power in the Yukon.* Sigma Resource Consultants Ltd. et al. January 1975.

MH80 Mining Hydro Power Study of Small to Mid-size Developments in East-Central Yukon. Monenco Consultants Pacific Limited. November 1980.

4.3 SUMMARIES OF PREVIOUS STUDIES

Table 4-1 presents in summary form the pertinent details of the eleven relevant studies listed in Section 422. The summaries indicate the number of sites investigated by each study; and describe the field work, topographic and geological mapping, and hydrology carried out, the design criteria used, the extent of socio-environmental constraints considered, the basis for the cost estimates produced, and the principal results and conclusions of the study. Based on the criteria set out in Section 312, each summary also includes an assessment of the level of the study (i.e. whether Pre-reconnaissance, Reconnaissance, Inventory, Prefeasibility, or Feasibility).

More detailed summaries of each of the studies are contained in Appendix C.

TABLE 4-1

Summarized Analysis of Previous Site Studies

Report	Sites	Study Level/Duration	Field Investigations	Topography	Geology	Hydrology	Design	Socio Environmental	Cost Estimate	Res
Interim Report on Hydroelectric Power Possibilities of Kluane River, Yukon Territory: Kluane Canyon Dam Site Water Resources Branch. May 1962 (KL 62)	1 power/storage site near Kluane Lake outlet	Inventory (Level C) Study period 1958-1962	Engineering 1 yr Geological and seismic survey 1 yr	Damsite topog 1:1200 10 foot contours by stadia. Reservoir: NTS 1:50,000 with 100' contours	Geological mapping on 1:1200 topog. Five seismic lines obtained	Hydrology based on 7 years of record (1953-1959) Design floods based on maximum projected rainfall	Mass concrete dam with integral spillway and intake/powerhouse. LF 50%. Drawing showing general layout and sections included.	Not addressed	Detailed estimate provided. Quantities given. Based on 1961 price levels. Reservoir clearing and socio-environmental mitigation costs not included.	16.5 MW p feasible $10.7 mil Energy co
Interim Report on Hydroelectric Power Possibilities of Ross River, Yukon Territory: Prevost Canyon Dam Site; Ross Canyon Dam Site Water Resources Branch. Nov.1962 (RP62)	1 Site at Ross Canyon 1 Site at Prevost Canyon	Inventory (Level C) Inventory (Level C) Study duration 1958-1962	Program of geological survey with seismic at Ross site. Stream guaging station set up in 1961 on Ross River. Aerial and ground recon, and ground surveys at both sites.	1:1200 topography with 10 foot contours for dam sites. 1:50,000 NTS maps for reservoirs.	Only Ross Canyon had geological mapping.	Based on 7 years of record for the Pelly River due to short record on the Ross River Flood estimate from hypothetical worst storm but no approp. meteorological records.	No general layouts in report. Rockfill dams at both sites. 50% load factor assumed.	Not addressed	Detailed estimates with some quantities given. Based on 1961 price levels. IDC included, but clearing and socio-envirnmental mitigation cost not included.	38 MW plan feasible w $21.7 mill 0.82¢/kWhr 12.4 MW pl feasible w $9.9 mill 1.26¢/kWhr
Yukon River Basin Study Water Resources Branch Dec. 1962 (YB 62)	17 major projects Two development plans. Major - no diversions Modified - Water diverted to Yukon-Talya or Yukon-Taku	Prefeasibility (Level D)	Engineering 3 yrs Geological & seismic survey 3 yrs Surveying - levels & stadia 5 yrs Materials search Stream guaging stations set up	Damsites mapped at 1:1200 to 1:2400, with 10 feet contours, by stadia tied to geodetic control. Reservoirs mapped from 50 foot form lines on airphotos	Surface geology mapped onto 1:1200 to 1:2400 topography. One or two seismic lines run at some sites. No drilling carried out.	Hydrology based on 13 years (1944-1957) of record from base station.	Two plans are included General Arrangement, and Elevations and Sections. Earthfill, Rockfill and Concrete Dams are used. LF 75%	Not addressed	Detailed estimates provided Quantities given. Not included: navigation, fish passage facilities, or other mitigation costs. Reservoir clearing costs included.	Major Plan energy cos Modified P firm energ
	2 diversion projects (Yukon-Yalya and Yukon-Taku	Reconnaissance (Level B)	None - data from previous studies NWPI, Alcoa, etc.	None	None	Modified plan assumes 24,000 cfs for diversion	From previous studies	Not addressed	No estimates given	Several pr Yukon-Taly Provides
	35 minor projects	Reconnaissance (Level B) on most sites Study period 1955-1962	Aerial recce on most sites. Ground investigations on a few.	Some sites mapped at 1:1200 to 1:2400, with 10 foot contours. Other sites studied from NTS mapping at 1:250,000, with 500 foot contours.	Surface geology mapped onto 1:1200 to 1:2400 topography where obtained. No mapping of other sites.	Variable, based on 0 to 13 years of record from base stations	Only head available and power potential given	Not addressed	No estimates	Site Ident descriptio potential

TABLE 4-1

nvironmental	Cost Estimate	Results/Conclusions	Remarks
ed	Detailed estimate provided. Quantities given. Based on 1961 price levels. Reservoir clearing and socio-environmental mitigation costs not included.	16.5 MW plant technically feasible at capital cost of $10.7 million. Energy cost 1.27¢/kWhr	Power canal might be investigated for greater head development. Any scheme here will augment flow control to lower Yukon River developments.
ed	Detailed estimates with some quantities given. Based on 1961 price levels. IDC included, but clearing and socio-envirnmental mitigation cost not included.	38 MW plant at Ross Canyon feasible with capital cost of $21.7 million and firm energy at 0.82¢/kWhr. 12.4 MW plant at Prevost feasible with capital cost of $9.9 million and firm energy at 1.26¢/kWhr.	Ross investigation superceded by 1982 pre-feasibility study. (RC 82). This Prevost Canyon study is still the most detailed available.
d	Detailed estimates provided Quantities given. Not included: navigation, fish passage facilities, or other mitigation costs. Reservoir clearing costs included.	Major Plan 6069 MW installed firm energy cost 0.45¢/kWhr Modified Plan 3453 MW installed firm energy cost 0.55¢/kWhr	Extensive studies, field work, etc. with detailed estimates for full development of the main stem. Other sites not required for this development not described. Caution required in using potential power figures since socio-environmental factors not considered. Conceptual designs for some sites require updating to current practice.
d	No estimates given	Several proposed schemes for Yukon-Taiya Yukon-Taku. Provides 3650 MW firm	Indicates alternative diversion projects reducing Major Plan power to Modified Plan output
d	No estimates	Site identification and some description. Head available and potential capacity estimated.	Useful in drawing attention to possible projects.

TAB

Report	Sites	Study Level/Duration	Field Investigations	Topography	
Report on Hydroelectric Power Resources of the Porcupine, Peel, and Rat River Region, Yukon and Northwest Territories Water Resources Branch. Apr 1965 (PP 65)	5 stage diversion scheme from Peel and Porcupine Rivers to power sites on Rat River. Alternate non-diversion scheme: Porcupine 2 sites Peel 2 sites	Inventory/Reconnaissance (Level C/Level B) Reconnaissance (Level B) Three year program	Field investigations extended to 2 seasons including aerial photography, aerial and ground reconaissance, ground and barometer surveys, river profiling, geological appraisal with limited seismic. Stream flow guaging stations established.	Damsite mapping produced to scales of 1:1200, 1:1800 or 1:2400 with 10 ft contours. Reservoir mapping carried out using aerial photos with barometer level ground control.	Geo Sel bed
A Preliminary Appraisal of the Yukon-Talya and Yukon-Taku Storage and Power Schemes Water Resources Branch. Aug 1966 (YT 66)	Diversion schemes 1. Yukon-Talya - 3 stage scheme or 2. Yukon-Taku - 7 stage scheme	Pre-feasibility (Level D) Pre-feasibility (Level D) Study duration: 2 years	No new field work undertaken. Use made of field investigations carried out for previous studies.	No new topography produced. Mapping available from previous studies at scales of 1:490 to 1:6000, and with 2 ft to 20 ft contours for damsites and 50 ft to 100 ft contours for reservoirs.	No app
Power Supply for the Yukon Montreal Engineering Co., Ltd. Mar./Jul. 1966 (PS 66)	10 sites studied for load in the Vangorda Creek area	Pre-reconnaissance (Level A) except: Granite Canyon - (B) Five Finger Rapids - (B) study duration less than 1 year	Limited to brief recon visits to six of the sites.	No new mapping. Used topog. 1:1200 or 1:2400 with 10 ft contours. Except for one site, mapping produced subsequent to 1962 Yukon Basin Study.	No
Hydroelectric Resources Survey of the Central Yukon Territory T. Ingledow & Associates Ltd. Jan. 1968 (CY 68)	55 sites studies of which 42 are potential, 3 are discarded Excluded Yukon R. main stem	Reconnaissance (Level B) Study duration: 5 months	Limited to helicopter reconnaissance and averaged less than 1 day per site. Barometer levels for key elevations and river profiles.	NTS 1:50,000 and 1:250,000 mapping used together with topog. from 1962 YRB study. No new topography.	New app sit

TABLE 4-1 (Cont'd)

TABLE 4-1

ld Investigations	Topography	Geology	Hydrology	Design	Socio Environmental	Cost Estimate	Results/Conclusions	Remarks
stigations extended to including aerial photo- rial and ground ce, ground and baro- eys, river profiling, appraisal with limited Stream flow guaging tablished.	Damsite mapping produced to scales of 1:1200, 1:1800 or 1:2400 with 10 ft contours. Reservoir mapping carried out using aerial photos with barometer level ground control.	Geological mapping. Seismic survey for bedrock levels.	Only 3 year record available. Extended by synthesis to 8 years. Firm flow based on 90% of 8 year average flow. 20% contingency added. No flood flow calculations.	Basic design criteria given re foundation treatment. Concrete, earthfill and rockfill dams used. General arrangement, sections and elevations given only for diversion schemes. 65% Plant factor assumed.	Not addressed	Estimates give only total capital costs and are based on 1964 price levels. 5% interest rate is assumed. No indication whether IDC and clearing costs are included.	Full diversion scheme with about 2000 MW capacity would cost $1 billion and provide firm energy at 0.6¢/kWhr. This is four times as much energy as non diversion scheme with energy at 0.7¢ to 0.8¢./kWhr.	A very substantial potential is identified with quite extensive studies. However, socio-environmental considerations could well reduce significantly the scheme and its attractiveness.
ld work undertaken. Use ld investigations for previous studies.	No new topography produced. Mapping available from previous studies at scales of 1:490 to 1:6000, and with 2 ft to 20 ft contours for damsites and 50 ft to 100 ft contours for reservoirs.	No new mapping or appraisal.	Available hydrometric records 1944-1964 are used. Design floods from U.S. Corps. of Engineers data.	Design criteria generally conform to those from 1962 YRB study. For each project 5 drawings are given, including 9 construction schedules	Noted that political and environmental factors were important, but were not addressed or allowed for in the estimates.	Summarised cost estimates are provided with some quantities given. 1964/1965 price levels govern. Interest rate used 5%. Reservoir clearing costs included.	Yukon-Talya has potential of 3410 MW firm capacity, about 20% more than for the alternative Yukon-Taku (2930 MW). Respective energy costs are 0.26¢/kWhr and 0.36¢/kWhr.	Energy costs for these large blocks of power are attractive but socio-environmental problems are major. These studies are for maximum development probably not acceptable.
brief recon visits to sites.	No new mapping. Used topog. 1:1200 or 1:2400 with 10 ft contours. Except for one site, mapping produced subsequent to 1962 Yukon Basin Study.	No new mapping.	Hydrology from 1962 YBR study updated.	Similar layouts to 1962 YRB study with earthfill rockfill and concrete dams. General layouts given for 5 sites. Additional plates for 5 Fingers and Granite.	Not addressed	Summarised cost estimates for 5 sites are given. Do not include S/E mitigation costs or reservoir clearing. Interest rate 5.625% assumed.	Most promising projects Granite Canyon 67-100 MW 5 Fingers Rapid 58-94 MW Energy costs from 0.6¢ to 1.2¢ per kWhr, lower than thermal for higher loads.	All sites except Prevost Canyon have been studied more recently to greater depth and so this study now superceded. Preliminary study of Frances River sites showed Upper Canyon promising.
helicopter reconnaiss- eraged less than 1 day evels for key eleva- iver profiles.	NTS 1:50,000 and 1:250,000 mapping used together with topog. from 1962 YRB study. No new topography.	New geological appraisal at only two sites.	Hydrometric record to 1965 utilised for various base stations. Firm flows based on average dry year flow.	Design criteria given in detail. Only mass concrete and rock fill dams used. Description of projects given but no drawings.	Not addressed	Estimating criteria given in detail. Capital cost estimates given as totals only except for four selected sites. Reservoir clearing costs included but not S/E mitigation.	Comparison of costs of energy from 42 projects is made. Estimates are however based on brief study with minimum input data.	Inadequate design and estimate information to allow proper review of studies to be made, however, clearly below inventory level. Conceptual designs described require updating for some sites.

TABLE 4-1 (Cont'd)

Report	Sites	Study Level/Duration	Field Investigations	Topography	Geology	Hydrology	Design	Socio Environmental	Cost Estimate	
Frances River Development Montreal Engineering Co., Ltd. Dec. 1969 (UC 69)	Upper Canyon site and alternative downstream site.	Inventory (Level C) (Same aspects to D level) Study duration: 6 mo.	Two reconnaissance and survey visits. Ground and barometer levels and surveys including dam site stadia. Field work about 1 week duration.	Dam site mapping at 1:1200 scale was produced from stadia data. Contour interval was 10 feet. For reservoir only 1:250,000 NTS sheets were available.	Geology of upstream site was obtained from GSC Topical Report No. 103 (1965)	Only a 6 year record (to 1968) was available on the Frances River. Correlation with Hyland River 11 year record was necessary. Design flood by freq. analysis	No design criteria were given but project details are well illustrated by several drawings contained in the report. A construction schedule was included. CF of 60% was adopted.	Not addressed in report. Flooding of Frances Lake by 45 feet was however seen as a major impediment to the scheme.	Detailed estimate with quantities is provided. Interest rate of 8% was used. Clearing costs were not included, nor were mitigation costs.	A 5 with kWhr cos econ
Power Survey of the Liard River Basin: Yukon and Northwest Territories T. Ingledow & Associates Ltd. Feb. 1970 (LB 70)	15 Yukon sites studies 8 selected for inventory (15 NWT sites also studied)	Inventory (Level C) for Liard and Frances River sites. Reconnaissance (Level B) for Hyland, Coal, and Beaver River sites. Study duration: 10 months	Helicopter recce visits over a 6 week period. Duration of visits 1 to 2 days per site. Barometer levels taken for key elevations and ground control for aerial photo mapping.	NTS 1:250,000 maps with some areas covered by 1:50,000 sheets with 100' contours. Augmented by maps from aerial photos with 20' contours as necessary. Some 1962 YRB maps used.	Geological maps produced by GSC for 1962 YRB study used.	18 years of record available from base stations 1000 year flood used.	Comprehensive design data given. Dam types limited to rockfill and mass concrete 60% CF used. General arrangement plan provided for each site.	Not addressed	Based on then currently southern Canada price levels, plus 25%. Estimating guidelines are given but no detailed estimates nor quantities. Total capital cost given include IDC and reservoir clearing. Interest rate 8-1/4%.	8 pr capa Firm 1¢ t
The Development of Power in the Yukon Sigma Resource Consultants Ltd. et al. Jan. 1975 (SI 75)	80 Yukon sites identified 17 sites selected 24 sites updated 39 unpromising (22 NWT sites also identified)	Reconnaissance level for selected sites (Level B) Study duration: about 1 year	Two survey trips each less than one month by fixed wing and helicopter. Some barometer levels taken during this reconnaissance.	Use was made of 1:250,000 and 1:50,000 NTS map sheets and also 1962 YRB study 10' contour sheets. New topog. was produced for one project only.	No new geological mapping.	24 year period of record to 1973 was used. Firm flow established as a proportion of long term meanflow established from data taken for several rivers. Spillway design taken as double 1964 peak.	No design criteria are given. A combined general location plan and single line layout is given for the selected projects only.	S/E overview is major part of report with backup data in Appendix. Probable effects on 21 selected projects are tabulated but no ranking fo S/E acceptability is attempted.	Project investimant cost estimates for 20 selected sites are given, showing breakdown into only about a dozen items. 1973 price levels are assumed. IDC is not included in estimates.	Cost capa are rang Hydr only prov
Mining Hydro Power Study of Small to Mid-Size Developments in East-Central Yukon Monenco Consultants Pacific Ltd. Nov. 1980 (MH 80)	4 sites Little Salmon Ross Canyon Hoole Canyon False Canyon	Reconnaissance (Level B) Study duration: 9 months	Helicopter reconnaissance including barometer levels at key locations. Duration of field work - 5 days	Dam site mapping with 5m contours was obtained from existing aerial phogography. NTS mapping at 1:50,000 and 1:250,000 for reservoir analysis	No new geological appraisal.	Hydrometric records available for periods of 14 to 20 years.	Detailed design criteria not given but a project layout plan for each site included. 60% CF assumed.	Not addressed. Separate S/E overview was commissioned later.	Estimate summaries provided for all 4 projects, with detailed estimate including quantities given for False Canyon the favoured scheme. 1980 price levels were used and estimates include fringe clearing costs, S/E mitigation costs not included. Interest Rate: 12% rate.	Reco Salm cons doub Fals Hoo Ross Litt Firm 8¢/k

TABLE 4-1

ocio Environmental	Cost Estimate	Results/Conclusions	Remarks
ddressed in report. ing of Frances Lake feet was however s a major ment to the scheme.	Detailed estimate with quantities is provided. Interest rate of 8% was used. Clearing costs were not included, nor were mitigation costs.	A 53 MW two unit plant feasible, with firm energy cost of 0.73¢/kWhr. However, heavy clearing costs not included which affect economic viability.	This economically atractive project depends on a 45' increase in Frances Lake level with possibly unacceptable socio-environmental consequences. It could be superceded by the False Canyon project with lower environmental impact but higher cost.
ddressed	Based on then currently southern Canada price levels, plus 25%. Estimating guidelines are given but no detailed estimates nor quantities. Total capital cost given include IDC and reservoir clearing. Interest rate 8-1/4%.	8 projects found feasible with capacity of 390 MW in total. Firm energy costs estimated from 1¢ to 2.1¢ per kWhr.	With 30 sites examined in a 10 month period it is not possible to be entirely confident of the 8 sites added to the inventory by these studies.
verview is major of report with data in Appendix. ble effects on 21 ted projects are ated but no ranking E acceptability is ted.	Project investimant cost estimates for 20 selected sites are given, showing breakdown into only about a dozen items. 1973 price levels are assumed. IDC is not included in estimates.	Costs per kW of installed capacity for 17 selected sites are compared in a table. These range from $630/kW to $1500/kW. Hydroelectric power is seen as only local energy source of proven availability.	Study covers vast area and attempts to review about 100 possible sites. Main stem of Yukon River is not closely investigated except for 5 Finger Rapids site. Socio-environmental considerations get equal or greater attention and considering one year study duration and budget restraints it is not surprising this study is judged only at Reconnaissance Level B.
ddressed. Separate verview was commis- later.	Estimate summaries provided for all 4 projects, with detailed estimate including quantities given for False Canyon the favoured scheme. 1980 price levels were used and estimates include fringe clearing costs, S/E mitigation costs not included. Interest Rate: 12% rate.	Recommended that only Little Salmon site can be dropped from consideration since cost/kW about double that of other sites. Cost/kW False Canyon 60 MW 3040 Hoole Canyon 38 MW 3640 Ross Canyon 30 MW 3895 Little Salmon 15 MW > 6450 Firm energy cost at Faro about 8¢/kWhr from False Canyon scheme.	False, Hoole and Ross Canyon site subsequently studied to pre-feasibility level D thus rendering these findings obsolete. The Little Salmon site might be re-examined for a lesser development if this becomes appropriate.

TABLE 4-2

Recent (1980-1983) Reports to Inventory Level or
Higher, Not Requiring Review or Updating

Report	Site/River	Capacity	Study Level	Cost Per kW Installed Capacity(1)(4)	Importance Rating(2)	Socio-Environ. Report	Remarks
Mid-Yukon	Mid-Yukon Ph 1	80 MW	E	$4,935	Average	Yes	
(MY80)	Yukon R. Ph 1/11	240 MW	E	2,280) 1,755	Important	Yes	
	Ph 111	240 MW	B	1,270)	Important	No	Requires upgrading to Level C
Teslin NWPI (TR80)	NWPI site Teslin River	55 MW	D	5,223	Minor	No	
Low Granite	Granite	40 MW	E	8,100	Minor	Yes	
(GC80)	Canyon Pelly River	120 MW	E	3,110	Important	Yes	
Atlin Lake Storage (AL80)	Atlin River	Storage	F	Storage Project	Important	Yes	
False Canyon (FC82)	False Canyon Frances River	58 MW	D	4,510	Average	Yes	
Ross Canyon (RC82)	Ross Canyon Ross River	30 MW	D	6,270	Average	Yes	
Hoole Canyon (HC82)	Hoole Canyon Pelly River	40 MW	D	3,740	Important	Yes	
Slate Rapids (SR83)	Slate Rapids Pelly River	41 MW	C	4,120	Important	No	Barely to Level C
High Granite (GC82)	Granite Canyon Ph 1	80 MW	E	4,615	Average	-	
	Pelly R. Ph 1/11	254 MW	E	2,570	Important	Yes	
Surprise Lake	Pine Creek Atlin Lake	10 MW (5)	D	2,940	Average	-	

Notes:
1) Costs in 1982 dollars.
2) See Part 5.
3) All sites in Zone 1 (see Part 5).
4) Costs include reservoir clearing and IDC, but not socio-environmental mitigation, escalation or transmission.
5) Several schemes and capacities examined.

TABLE 4-3

Studies and Sites not Included in Review

Report/River	Site/Capacity	Study Level	Zone	Reason for no Review	Potential	Remarks
YB62 Lapie	Lapie 1 MW	B	1	Mini hydro	Unpromising	
KA62/YB62 Kathleen	Kathleen R. 2 MW	C	2	Mini hydro	Unpromising	
CY68 Watson	Watson R. 3 MW	B	1	Mini hydro	Unpromising	
SQ82 Squanga	Squanga Cr. 2 MW	D	1	Mini hydro / recent study to D level	Attractive	
AD81	Aishihik Diversions	D	1	Plant addition / recent study to D level	Possible	
YB62 Nisutlin	Nisutlin River	B	1	Inadequate description and data		
YB62 Beaver	Beaver Canyon		2	Inadequate description and data		
MY80 Yukon	Cassiar Bar	A	1	Inadequate description and data	Possible	Important as next stage to Mid-Yukon Project.
Alsek	Alsek Canyon	A	1	Not yet studied	Substantial	In Kluane Park.
Pelly	Hoole R. 15 MW	A	1	Not yet studied	Promising	Important for optimum Upper Pelly River development.
Pelly	Campbell Cr. 20 MW	A	1	Not yet studied		
CY68 Chandindu	Chandindu 6 MW	A	2	Dam only appraised and estimated	Unpromising	
BC82 Racine	Racine 8 MW	A	1	Inadequate description, data, with no field investigation	Low for B.C.H.P.A.	Some of B.C. sites may have potential for Yukon loads.
BC82 Tutshi	Tutshi 13 MW	A	1	Inadequate description, data, with no field investigation	Low for B.C.H.P.A.	Some of B.C. sites may have potential for Yukon loads
BC82 Wann	Powerhouse 9 MW	A	1	Inadequate description, data, with no field investigation	"	"
BC82 Atlin	Taku 17 MW	A	1	Inadequate description, data, with no field investigation	"	Also ref. WH77
BC82 Gladys	Hall Lake 11 MW	A	1	Inadequate description, data, with no field investigation	"	Some B.C. sites may have potential for Yukon loads

TABLE 4-3 (Cont'd)

Report/River	Site/Capacity		Study Level	Zone	Reason for no Review	Potential	Remarks
BC82 Gladys	Gladys	7 MW	A	1	Inadequate description, data, with no field investigation	"	Some B.C. sites may have potential for Yukon loads
BC82 Swift	Swift	52 MW	A	1	Inadequate description, data, with no field investigation	"	"
BC82 Jennings	Jennings	8 MW	A	1	Inadequate description, data, with no field investigation	"	"
BC82 Homan	Bennett	15 MW	A	1	Inadequate description, data, with no field investigation	"	"
BC82 Warm Ck.	Kirtland	12 MW	A	1	Inadequate description, data, with no field investigation	"	"
BC82 O'Donnel	O'Donnell	8 MW	A	1	Inadequate description, data, with no field investigation	"	"
BC82 McNaughton	McNaughton	12 MW	A	1	Inadequate description, data, with no field investigation	Low for B.C.H.P.A.	Some of B.C. sites may have potential for Yukon loads
Morley River		0.75 MW	B	1	Mini hydro/recent study		Studies by Yukon Electrical
McIntyre Creek		0.75 MW	F	1	Mini hydro/recent study		Studies by Yukon Electrical
Frances River	Middle Canyon	5 MW	B	1	Mini hydro/recent study		Studies by Yukon Electrical
Liard River	Liard Canyon	5 MW	B	1	Mini hydro/recent study		Studies by Yukon Electrical
Watson Lake McDonald Creek	Watson Lake	2.5 MW	B	1	Mini hydro/recent study		Studies by Yukon Electrical
Alsek/Tatshenshini Diversion				1	Partial study cannot be assessed		Map study only, with no allowance for storage
Klondike River	North Fork	10 MW		2	Rehabilitation of obsolete plant		Mini hydro
GSC Topical Reports not Reflected in Hydro Studies							
GSC15 Yukon	Fort Selkirk			1	Geological and topographic only		
GSC18 Yukon	Selwyn			1	Geological and topographic only		
GSC25 Pelly	Gerc			1	Geological and topographic only		Alternate to Braden's Canyon
GSC102 Stewart	Five Mile Rapids			2	Geological and topographic only		
GSC16 Yukon	Fort Selkirk Saddle			1	Geological and topographic only		
GSC14 Yukon	Wolverine Draw			1	Geological and topographic only		
GSC12 Yukon	Five Fingers Draw			1	Geological and topographic only		
GSC21 Yukon	Lower Ogilvie			2	Geological and topographic only		
GSC16 Yukon	Lower Dawson			2	Geological and topographic only		

PART 5

EVALUATION OF THE EXISTING HYDROELECTRIC INVENTORY

5.1 EVALUATION OF THE EXISTING HYDROELECTRIC INVENTORY

An examination of Tables 4-1, 4-2 and 4-3 (see Part 4) reveals the patchwork nature of the existing studies. The studies spread over a 20 year period are by several independent entities, and to widely divergent levels with different design and estimating criteria.

Some sites are covered by two or more reports with different authorship and at different levels of study. Acceptance of the most recent report as definitive for the inventory would be normal but not necessarily so if this is at a lower level than the earlier study. Economic ranking cannot be carried out with confidence, in part because estimates have in some cases been made with a bare minimum of input data, little precedent from non-existent current hydro cost information and also during a period of roller coaster escalation. A hydroelectric dollar in 1960 in fact was worth more than four current (1983) dollars. Hydrology has been studied based on flow records varying between 2 years and 20 or more years. Input data ranges from adequate to inadequate.

It should be noted at this point that the evaluation of these reports does not imply criticism of how the studies were carried out within the framework of their terms of reference, and of time and budget limitations. It appears likely, for example, that the funding and/or time allocated to such studies as CY68 and SI75 could not support the work we have defined as necessary in an Inventory Level C investigation.

Excluding investigations carried out prior to 1960, most of which are unpublished and superceded by more recent reports, the studies carried out from 1960-1983 can be classified in three main groups in a rather simplistic manner:

Group 1

A group of studies prepared between 1960 and 1967 carried out by the Water Resources Branch, Department of Northern Affairs and National Resources covering the major potential projects on the Yukon River and its principal tributaries, together with major sites in the Northern Yukon on the Porcupine and Peel River. These studies, generally to Level C or D, involved several years of field survey and investigations including geological appraisal and reports by GSC on over 50 sites. Much original input data was collected, and detailed hydro investigations covered about 20 potential major projects to a pre-feasibility level. As such this would form a reliable inventory of most major projects after some updating. However, this optimum development program was envisaged without relation to any socio-environmental concerns, some of which would undoubtedly severely modifiy the proposed river development.

Group 2

A group of studies between 1968-1978, generally at less than Inventory Level, of which the Sigma Resource Consultants report and the two T. Ingledow studies covered the entire Yukon, the only exception being most of the Yukon River main stem. The majority of these studies provided a minimum of field investigation generally utilizing site identification and data from earlier studies and are rated at Reconnaissance level B. Estimates given must be considered most preliminary and are only appropriate for comparison of projects within an individual study, rather than with sites studied by others. However this group of studies provide the most recent inventory information on about 40 potential projects.

It is not judged that these investigations provide an adequate inventory based on the input data available and the time allowed for some of the studies. In addition socio-environmental impacts were only considered for about one half of the projects.

Group 3

The third group of about 10 studies have been carried out during the last five years, most to a Pre-feasibility Level D or E but all at least to Inventory level. These, ranging from mini hydro to mega projects, have been chosen to prepare for meeting specific loads including the proposed gas pipeline, and mining expansion in the lead/zinc belt. These recent studies are regarded as adequate for inventory purposes and have been carried out in most cases in conjunction with socio-environmental appraisals. With some additional field investigation and mapping required in a few cases they can be treated with confidence to assist in the choice of the next Yukon hydro development and for long term resource planning.

Besides the investigations forming these three groups there are some reports on individual sites, the most important being an appraisal of the Yukon-Taiya and Yukon-Taku diversion mega projects both based on data from previous studies. The study of these mega projects may be considered with Group 1 although, unlike the others, it has not been based on original input data.

Considering that recent investigation work has turned up several attractive sites which were not discovered in earlier studies it is likely that there are many other unidentified sites. It was further established that other sites were noted on the Yukon River during the 1962 Yukon River Basin study but discarded since they did not fit into the optimum river development selected. These may be important if different sites must be adopted in response to socio-environmental impacts.

Finally there are virtually no studies until the last few years identifying mini hydro sites less than 5 MW. This inventory gap is possibly of importance where small local loads must be supplied.

5.2 PRIORITIES FOR STUDY UPGRADING AND UPDATING

With limited time and money available for upgrading past study work and for proceeding with new investigations, it is necessary to decide on a rational basis which sites and rivers should be addressed first. This decision should be guided by a ranking based on the best existing information available with an added judgement factor. Tables 5-1 and 5-2 have been prepared in consideration of the following major rating factors:

- The relative importance of the potential project as a part of the Basin hydro resource. This takes into account the project's magnitude, its apparent economic attractiveness and also how soon it might be required.

- The apparent adequacy of the appropriate study as part of a reliable resource inventory. This attempts to combine the study level, quality of input data, degree of field work and requirement for updating.

Taken together these two factors are seen as providing a reasonable rating for the priorities to be used for study upgrading and updating so that the resulting progressively improving inventory will meet both the short term need for choice of sites for early development and the parallel need for long term planning.

5.3 PROJECT IMPORTANCE

It can be seen that size and economic attractiveness are both key factors in assessing how important is a potential project as part of the hydro resource. At the margin, a mini hydro plant is such a small proportion of the total Yukon potential that it can be important only in meeting small local loads. In a like manner unless a mega project has a benefit cost ratio greater than unity it is not of significant importance. A large capacity plant with a high benefit cost ratio (more common with large plants) is of major importance.

There is however a countervailing factor to mega project importance, and that is the probability that a major load requiring its development will not develop for many years. This will reduce its present importance by a time discount factor.

A further factor which modifies the rating based on size and economy is the location of the site relative to potential future load centres. The basin and Territory has been divided up into 3 zones as shown on Plate 2-1, located at the end of Part 2, with favourable location rating being largest in Zone 1, lower in Zone 2 and lowest in Zone 3. This rating will reduce the importance of remote mega projects.

Socio-environmental considerations have been taken into account or studied on less than half the projects reviewed, and most of those only to a level which did not justify site ranking. Accordingly, the importance of this factor could not be given full influence. However, it was decided to flag those sites which appeared to have major socio-environmental problems likely to modify or prevent development, and this is reflected in the importance rating.

The basis for the ratings is given in Table 5-1(a).

Both the size and economic factors have been calculated on a non linear basis to take account of the different requirements of short, medium and long term development. For example in the short term, the cost/kW installed of medium size plants has been compared with the approximate diesel power equivalent. At the same time all projects have been rated compared only with other projects in the same or associated study, rather than with projects studied by another group at a different time. Another example of the different treatment felt necessary for smaller plants which are more important in the short term, as compared with large plants for the long term, is the consideration given to size. While importance increases with size, a linear relationship is not assumed.

The project Importance ratings, in three categories: high - "I", average - "A" and minor - "M" can be studied in Table 5-1 and Table 4-2. These must of course be treated as a rough indication only, based on the rating system described, and a measure of judgement used to modify the result in a few cases. The shortcomings of the input data are again stressed, particularly in the case of the "Power Benefit" and "Socio-environmental" ratings, as are the hazards of prediction for the "Timing" and "Location" factors.

An examination of the importance ratings reveals the sites fall roughly into three categories of high - "I", average - "A", and minor - "M" importance.

The "I" group is virtually identical with Group 1 described earlier in this Section and includes most mega projects on the Yukon, Pelly, and Stewart Rivers and also the Yukon-Taiya/Taku diversion projects. This top ranking in importance reflects the magnitude of the projects and their relatively low cost per kilowatt. It is despite the discounting due to the probability that these projects would not be required for many years and also in some cases despite significant negative socio-environmental problems. The "I" group, however, also contains one or two of the most attractive mid-sized projects which are favourably located for early development, such as the Hoole Canyon project.

The "A" group are mostly medium size projects less than 100 MW capacity and include sites such as False Canyon which, while providing higher cost power than the first group, are seen as quite likely to be required in the near future for forseeable load growth.

The "M" group are of lower importance and have a low average capacity and relatively high cost. In some cases their location rules out economic transmission to probable load centres.

It should be noted that there are more than a dozen sites in British Columbia and Yukon in Table 4-3 that cannot be properly assessed for importance on the existing data, and probably more sites that have not so far been discovered.

5.4 INVENTORY DATA AND STUDY ADEQUACY

541 BASIS FOR THE RATING

The reliability of a hydroelectric site inventory is dependent on two main factors: the adequacy of the data which is used in the conception and evaluation of the potential projects; and the level to which the work is carried out. Although these two aspects are interdependent, they must be considered separately when assessing the reliability. If they are not, a misleading or erroneous conclusion may be reached. For example, a study which is carried out to an apparently high level may create the impression of reliability and adequacy, when in fact it may not be, due to incomplete, innaccurate or outdated information and data.

The data which is used to conceive and assess a potential hydroelectric project includes, but is not limited to, five main categories: field investigation data; topographic mapping; geological mapping and geotechnical assessment; hydrology and streamflow data; and cost estimating. Each of these is addressed separately as follows:

Field Work

The adequacy of the field investigations for the inventory studies has been rated on the basis of the report descriptions of the work accomplished and the duration of the site visits. For an Inventory Level study, a two week site investigation is considered desirable, and two days the minimum. The work must include an engineering appraisal of the site, assessing whether the location is the proper one; a preliminary examination of the surficial and bedrock geology; the taking of photographs; and the determination of key elevations for river profiles and aerial mapping.

Topography

Suitable topographic mapping of a potential damsite is required for determining the hydraulic head which can be developed, and for preparing engineering layouts of the powerhouse, control structures, spillways and diversion works required. These layouts lead in turn to the calculation of construction quantities to be used in the preparation of cost estimates. Topographic mapping of the reservoir area is also required, for determining the volume of storage which can be developed, and the amount of land which must be cleared.

To meet the requirements for an Inventory Level study, it is considered that mapping of the damsite at a contour interval of 10 ft (3 m), from either a ground-based survey or low level aerial photography with ground control is fully adequate. Mapping with a contour interval of 25 ft (8 m), developed from high level aerial photography, and with barometer level elevations at key locations is considered to be barely adequate. For many parts of Yukon, available mapping is limited to 1:50,000 scale National Topographic System maps with 100 foot contours, or even 1:250,000 scale maps with 500 foot contours. Except for mapping of reservoirs where 1:50,000 scale mapping with 100 foot contours or better is adequate, these are clearly inadequate for an Inventory Level study of a site due to their lack of detail. Furthermore, some substantial errors have been found in them during previous studies.

Geotechnical

Geotechnical appraisals of potential sites are required for determining the appropriate locations of dams and structures, for calculating the amount of work required in the preparation of foundations, and for locating sources of construction materials.

For an Inventory Level study, geological surface mapping of the site is required, together with minimum sub-surface investigation in the form of seismic profiling, perhaps with a single borehole for correlation and confirmation.

Hydrology

Hydrology is probably the most important single component of the data required for a site evaluation. The key element in the viability and attractiveness of a hydroelectric project is the amount of water which is available for power generation. This includes both the dependable, or firm, flow which can be developed on the river with the amount of reservoir storage available, and the average flow which can be expected. Also important in the design of the project is the maximum or flood flow which might occur. Calculations to determine these parameters are made using either measured flows on the river, or synthesized flows developed from precipitation patterns, drainage areas and watershed characteristics. In general, the reliability of the flow calculations increases with the length of the period of streamflow (hydrometric) data. In Yukon, hydrometric data for many rivers is either non-existent, or is of fairly short duration. As a result, hydrological calculations are often a combination of the two methods described above.

In rating the overall adequacy of the hydrology portion of a study, the need for updating must be addressed in addition to the data adequacy and depth of study. With the benefit of additional years of hydrometric record it may be possible to identify changes in critical low flows, long term mean flows, and maximum flows. Such changes can effect the energy capabilities of potential projects, as well as the required size of spillway and diversion structures. Wherever possible, the present hydrometric record has been compared, but not in detail, with that available at the time of the original study to identify the significance of any such changes. However, some of the studies contained insufficient information on the lengths of the critical flow periods used, to provide a ready basis for comparison. Nevertheless, the comparisons give some indication of sites where updating may lead to significant differences.

Cost Estimating

The need to produce reliable project cost estimates at the Inventory Level of investigation is self evident. Such estimates provide a basis for the comparative evaluation of alternative developments. When combined with the data from the hydrological calculations, the estimates can be used to indicate an approximate cost of the energy which could be produced from the sites. Unreliable estimates can lead to incorrect conclusions regarding the attractiveness of potential proects, and can result in sites being improperly rejected or accepted for further study. Cost estimates are developed from the conceptual designs and layouts produced for potential sites. In turn, these are based to a large extent on the topography, geology and hydrology of the sites. Inadequacies in these elements will therefore lead to corresponding deficiencies in the cost estimates.

Study Depth

The level of study from A to F has been assigned in Table 4-1 based on the appraisal of the studied reports.

Outdate Factor

While outdating of hydrology has been taken into account in that rating factor, there are several other factors in the studies which can become out of date. An outdate judgement factor has been included to take into account the need to bring conceptual designs with relative construction costs into line with current practice.

Socio-Environmental Studies

Socio-environmental studies have not been included as part of the combined adequacy rating. Table 5-2 shows only whether any socio-environmental study has been carried out. Such studies will of course be required for site selection purposes, and a lack of even preliminary studies represents a serious deficiency in overall planning information.

Combined Adequacy Rating

The aggregate of all rating points of the seven rated factors might provide a rough measure of study adequacy. However gross inadequacy of one factor may be cloaked by high ratings in others. This could give a false overall appraisal of adequacy. For this reason a combined points rating was not given in the tabulation but instead the number of factors out of seven which were found to be inadequate is provided.

Finally, for simplicity the sites were grouped into three categories.

- S - satisfactory when 1 or 2 deficient factors rectified.
- D - deficient in 3 or 4 factors.
- U - unsatisfactory in 5 to 7 factors.

Table 5-2(a) describes the basis on which the inventory data adequacy ratings shown in Table 5-2 were developed.

542 DISCUSSION OF RESULTS

A summarization of the results of the rating of the inventory data and study adequacy presented in Table 5-2 is simplified by considering the studies in the same groupings described earlier, in Section 5.1. In brief, they are:

Group 1

The various studies produced between 1960 and 1967 by the Water Resources Branch, Department of Northern Affairs and National Resources.

Group 2

The group of studies carried out between 1968 and 1978, of which the principle ones are the 1975 Sigma Resource Consultants study (SI75), and the 1968 and 1970 T. Ingledow & Associates Limited studies (CY68 and LB70).

Group 3

The group of studies carried out during the past five years.

Only Groups 1 and 2 are of concern in this discussion since as previously explained it has been determined that the Group 3 studies are at least to Inventory Level, and are based on adequate, up-to-date data.

The rating results for each of these groups will be discussed in turn.

Group 1

The three main Group 1 studies reflected in Table 5-2 are the 1962 Yukon Basin Study (YB62), the 1965 Porcupine, Peel and Rat River study (PP65), and the 1966 Yukon-Taiya/Yukon-Taku study. A single site, Kluane Canyon, is also included, in a 1962 study of the Kluane River (KL62).

The sites investigated by the 1962 Yukon Basin Study (YB62) and appearing in Table 5-2 have been rated as being to Pre-feasibility Level overall. It can be seen that the hydrological studies and data have been concluded to be generally adequate. This is mainly a reflection of the fact that a good length (10 to 15 years) of hydrometric data was available for the sites considered, and that the more recent data has shown little change in flows. Two notable exceptions are Detour Canyon and Braden's Canyon; however, the hydrology for these sites was updated during the 1975 Sigma study and this is reflected in the ratings given in Table 5-2. The field work, and topographic and geotechnical components of the study have been found to be fully adequate for inventory purposes. This is due to the detailed topographic/geological mapping of the sites carried out by the Water Resources Branch/Geological Survey of Canada. The cost estimates have also been rated as adequate, being highly detailed, and having quantities for many items.

The 1965 Porcupine, Peel and Rat River study (PP65) has been found to be only marginally adequate with regard to the hydrology, because of a very short period of record (3 years) and the need for updating due to increases of up to 15% in flows up to the present. The hydrology for the Aberdeen Falls and Bell sites has been rated as adequate as a result of updating carried out during the 1975 Sigma study (SI75). The field work, topography, and geology have been found to be adequate, again due to the detailed mapping produced by the Water Resources Branch/Geological Survey of Canada. The level of cost estimate detail in the report is very low, and no quantities are given. Consequently, the estimates are rated as inadequate.

The 1966 Yukon-Taiya/Yukon-Taku study (YT66) made use of previously collected data from a number of different sources. The hydrology however, was updated. Because of the variety of sources, the topographic/geological mapping is not to a common standard, and is variable with regard to scales, contour intervals and degree of detail. Nevertheless, it has been found to be adequate overall, as have the field work, cost estimates, and the hydrology.

Group 2

Three principal Group 2 studies cover sites listed in Table 5-2. They are: the 1968 and 1970 T. Ingledow & Associates Limited studies of the Central Yukon and the Liard Basin, respectively (CY68 and LB70); and the 1975 study by Sigma Resource Consultants et al (SI75). Sites at Upper Canyon on the Frances River, Tagish Lake, and Little Salmon are covered by three other separate studies.

With only one exception, the hydrology for all of the 1968 Ingledow study (CY68) sites included in Table 5-2 has been found to be inadequate, mostly because of a complete lack of hydrometric data for most of the rivers under consideration. The exception is Mayo "B" which has been rated as barely adequate. Although it is near to a streamflow gauging station, the data has been found to be outdated because of a 15 to 20% drop in the minimum recorded flows. No topographic mapping was produced by the study. Therefore, most sites are rated as inadequate. Exceptions are Prevost Canyon, and Lower Canyon on the White River for which Water Resources Branch topography was available. The same comments apply to geology as to topography, except that in addition to the two sites previously mentioned, brief geotechnical reconnaissances of the Tay and Two Mile Canyon sites were carried out as part of the study. These are rated as having been barely adequate. Based on the documentation contained in the report, none of the cost estimates are considered adequate, due to a lack of detail and an absence of quantities. The field work has also been rated inadequate, having averaged less than one day per site. Although it is possible that some sites may have received more than this average amount of attention, there is no such documentation in the report.

The hydrology carried out for the 1970 Ingledow study (LB70) is rated as adequate for sites on the Liard, Frances and Hyland Rivers, and inadequate for those on the Beaver and Coal Rivers. The inadequacies result from the fact that there were no gauging stations near the sites. The topography and geology are rated as barely adequate to adequate for all of the sites except Hyland Diversion where the topography is inadequate. All of the cost estimates are inadequate due to a complete lack of detail in the report. At an average of only one to two days per site, the field work has also been rated as inadequate.

All of the sites in Table 5-2 referenced to the 1975 Sigma study (SI75) were found to have adequate hydrology data, with the exception of Tatshenshini and Bates Canyon for which virtually no hydrology work was done. Topography was found to be inadequate at Bates Canyon, barely adequate at Tatshenshini and Primrose/Kusawa, and adequate at Fraser Falls and Five Finger Rapids. Geotechnical appraisals were non-existent at Tatshenshini, Bates Canyon and Primrose/Kusawa, but were adequate at Fraser Falls and Five Finger Rapids where earlier mapping had been carried out by the Geological Survey of Canada. The cost estimates as presented in the report were found to be inadequate due to a lack of detail. Although no information is given in the report on the field time spent at each site, the large number of sites visited during two brief survey trips leads to the conclusion that the field work was inadequate.

The 1969 Montreal Engineering study (UC69) of the Upper Canyon site on the Frances River was rated as barely adequate, for field work and geotechnical assessment, and adequate with respect to topography, hydrology and cost estimating.

In both groups 1 and 2 there are many sites where updating of conceptual design is required. This can be noted best on the 1962 Yukon River Basin study (YB62) treatment of the main stem Yukon River plants, but is also evident in the 1968 central Yukon study (CY68), as far as can be determined from the descriptions of the structures.

TABLE 5-1
Importance Rating of Inventory Sites Reviewed
(See Table 4-2 for Recently Studied Sites)

Basin/River	Project	Report[1]	Capacity (MW)	Location Zone[2]	Rating of Project Importance[3]				Remarks
					Power Benefit Factor	Timing/ Location Factor	Socio-Environ. Factor	Importance Rating	
Alsek Basin									
Tatshenshini	Tatshenshini	SI75	160	1	Medium	Mid	Negative	Average	
Bates	Bates Canyon	SI75	110	1	Small	Mid	Favourable	Average	In Kluane Park
Liard Basin									
Liard	Liard Canyon	LB70	120	1	Small	Mid	Average	Average	
Frances	Upper Canyon	UC69	60	1	Small	Early	Negative	Average	
Frances	Lower Canyon	LB70	36	1	Small	Early	Average	Average	
Hyland	Hyland Diversion	LB70	–	1	Small	Early	Average	Average	
Beaver	Saucy Creek	LB70	46	2	Small	Mid	Average	Average	
Beaver	Beaver Crow	LB70	82	2	Small	Mid	Average	Average	
Beaver	Fantasque	LB70	78	2	Small	Mid	Average	Average	
Coal	Quartz Creek	LB70	38	1	Small	Mid	Average	Average	
Peel Basin									
Peel	Aberdeen Falls	PP65	450	3	Medium	Late	Average	Average	Also ref. SI75
Peel	Bonnet Plume	PP65	200	3	Medium	Late	Average	Average	
Peel	Peel Diversion	PP65	755	3	Medium	Late	Average	Average	
Pelly Basin									
Pelly	Detour Canyon	YB62	Storage/100	1	Small	Mid	Average	Average	Also ref. SI75
Pelly	Braden's Canyon	YB62	180	1	Medium	Mid	Average	Average	Also ref. SI75
Anvil	Anvil Creek	CY68	10	1	Small	Early	Average	Average	
Tay	Tay	CY68	31	1	Small	Early	Average	Average	
Earn	Earn	CY68	7	1	Small	Early	Average	Average	
Ross	Prevost Canyon	CY68	12	1	Small	Early	Average	Average	
Mica	Mica Creek	CY68	10	1	Small	Early	Favourable	Average	
							Average	Minor	
Porcupine Basin									
Bell	Bell	PP65	110	3	Small	Late	Negative	Minor	Also ref. SI75
Porcupine	Porcupine Canyon	PP65	190	3	Small	Late	Negative	Minor	
Porcupine	Porcupine Diversion	PP65	1200	3	Large	Late	Negative	Average	

Table 5-1 (Cont'd)

					Rating of Project Importance[3]				
Basin/River	Project	Report[1]	Capacity (MW)	Location Zone[2]	Power Benefit Factor	Timing/ Location Factor	Socio-Environ. Factor	Importance Rating	Remarks
Stewart Basin									
Stewart	Low Fraser Falls	SI75	100	2	Small	Mid	Average	Minor	
Stewart	High Fraser Falls	YB62	347	2	Medium	Mid	Average	Important	
Stewart	Independence	YB62	430	2	Medium	Mid	Negative	Average	
Stewart	Porcupine	YB62	223	2	Medium	Mid	Average	Average	
Stewart	Seven Mile Canyon	CY68	10	2	Small	Mid	Average	Minor	
Stewart	Big Kalzas Lake	CY68	17	2	Small	Mid	Average	Minor	
Hess	Two Mile Canyon	CY68	12	2	Small	Mid	Average	Minor	
Hess	Hess Canyon	CY68	53	2	Small	Mid	Average	Minor	
Hess	Rogue	CY68	18	2	Small	Mid	Average	Minor	
Pleasant	Pleasant Creek	CY68	5	2	Small	Mid	Average	Minor	
Ethel	Ethel Lake Diversion	CY68	8	2	Small	Mid	Average	Minor	
Mayo	Mayo B	CY68	9	2	Small	Early	Favourable	Average	
Lake	Lake Creek Diversion	CY68	13	2	Small	Mid	Average	Minor	
McQuesten	North McQuesten	CY68	5	2	Small	Mid	Average	Minor	
White Basin									
White	Upper Canyon	CY68	16	2	Small	Mid	Average	Minor	
White	Lower Canyon	CY68	16	2	Small	Mid	Average	Minor	
Kluane	Kluane Canyon	KL62	8	2	Small	Mid	Average	Average	Also ref. CY68
Donjek	Donjek	CY68	43	2	Small	Mid	Average	Minor	
Lower Yukon Basin									
Sixty Mile	Sixty Mile Diversion	CY68	18	2	Small	Mid	Average	Minor	
Forty Mile	Forty Mile	CY68	16	2	Small	Mid	Average	Minor	
Fifteen Mile	Fifteen Mile Diversion	CY68	7	2	Small	Mid	Average	Minor	
Indian	Indian	CY68	6	2	Small	Mid	Average	Minor	

Table 5-1 (Cont'd)

Basin/River	Project	Report[1]	Capacity (MW)	Location Zone[2]	Rating of Project Importance[3]: Power Benefit Factor	Timing/ Location Factor	Socio-Environ. Factor	Importance Rating	Remarks
Yukon Basin									
Yukon	Miles Canyon	YB62	Storage	1	Medium	Mid	Negative	Average	
Yukon	Hootalinqua	YB62	259	1	Medium	Mid	Average	Average	
Yukon	Big Salmon	YB62	301	1	Medium	Mid	Average	Average	
Yukon	Low Five Fingers	SI75	75	1	Small	Early	Average	Average	Also ref. PS66
Yukon	High Five Fingers	YB62	455	1	Large	Mid	Negative	Important	
Yukon	Wolverine	YB62	476	1	Large	Mid	Average	Important	
Yukon	Britannia	YB62	459	1	Large	Mid	Average	Important	
Yukon	Ogilvie	YB62	896	2	Large	Late	Negative	Important	
Yukon	Dawson	YB62	571	2	Large	Mid	Negative	Important	
Yukon	Boundary	YB62	1006	2	Large	Late	Average	Important	
Yukon	Yukon-Taiya	YT66	4050	1	Large	Mid	Negative	Important	
Yukon	Yukon-Taku	YT66	3690	1	Large	Mid	Negative	Important	
Yukon	Tagish Storage	Unpub.	Storage	1	Medium	Early	Favourable	Average	
Teslin	Swift	YB62	158	1	Small	Mid	Negative	Minor	
Wolf	Wolf	CY68	13	1	Small	Early	Average	Minor	
McNeil	McNeil	CY68	10	1	Small	Early	Average	Minor	
Big Salmon	Quiet Lake/Nisutlin	CY68	15	1	Small	Early	Average	Minor	
Takhini	Primrose/Kusawa	SI75	60/17?	1	Small	Early	Favourable	Average	Also ref. CY68 SI75
Little Salmon	Little Salmon	MH80	15	1	Small	Early	Average	Average	
Little Salmon	Drury Lake	CY68	4	1	Small	Early	Average	Average	

Notes:

[1] Refer to Bibliography, Part 7

[2] Refer to Plate 5-1

[3] Refer to Text, Part 5

TABLE 5-1(a)

Derivation of Ratings in Table 5-1

Importance Ratings	
Power Benefit Factor	Rating is based on Installed Capacity in MW and possible power cost. Rating ranges from Large through Medium to Small. Large benefit reflects the combination of a large and low cost plant.
Timing/Location Factor	Study area split into 3 zones of increasing distance from probable load centres. - Zone 1 Yukon Territory between 60° and 63° latitude* 127° and 138° longitude - Zone 2 Yukon Territory between 60° and 65° latitude less Zone 1 - Zone 3 Yukon Territory between 65° latitude and Arctic Ocean shoreline * includes B.C. portion of Yukon Basin. Probability of early development is assumed highest for Zone 1, decreasing through Zone 2 and lowest in Zone 3. This is combined with the assumption that early development is least likely for the largest projects, and a Timing/Location rating is given ranging from Early through Mid-term to Late development.
Socio-environmental	Projects that appear likely to suffer major modification or reduction in size destroying economic viability receive a Negative rating. Other projects are rated subjectively, with those about which nothing significant is known receiving an "Average" rating.
Importance Rating	The above factors are combined with the exercise of judgement to produce an Importance rating ranging from Important through Average to Minor.

TABLE 5-2

Rating of Site Inventory Data and Study Adequacy

				Rating of Inventory Data and Study Adequacy[2]									
Basin/River	Project	Report[1]	Field Work (10)	Topography (10)	Geotech. (10)	Hydrology (10)	Estimating (10)	Out-Date (10)	Study Level/ Depth (/10)	Number of Deficient Factors (7)	Adequacy Category[3]	Socio-Environ. Study?	Remarks
Alsek Basin													
Tatshenshini	Tatshenshini	SI75	2	6	0	1	3	6	B / 3	5	U	Yes	
Bates	Bates Canyon	SI75	2	3	0	1	3	6	B / 3	6	U	Yes	
Liard Basin													
Liard	Liard Canyon	LB70	3	8	10	8	3	7	C / 5	2	S	Yes	
Frances	Upper Canyon	UC69	5	7	6	7	10	6	C / 5	0	S	Yes	
Frances	Lower Canyon	LB70	3	8	10	8	3	6	C / 5	2	S	Yes	
Hyland	Hyland Diversion	LB70	2	3	6	8	1	5	B / 3	4	D	No	
Beaver	Saucy Creek	LB70	3	7	6	3	1	6	B / 3	4	D	No	
Beaver	Beaver Crow	LB70	3	7	6	3	0	6	B / 3	4	D	No	
Beaver	Fantasque	LB70	3	7	6	3	1	6	B / 3	4	D	No	
Coal	Quartz Creek	LB70	3	6	6	4	0	6	B / 3	4	D	No	
Peel Basin													
Peel	Aberdeen Falls	PP65	10	8	10	7	3	6	C / 5	1	S	Yes	Also ref. SI75
Peel	Bonnet Plume	PP65	10	8	10	4	1	3	B / 3	4	D	No	
Peel	Peel Diversion	PP65	10	8	10	5	1	5	B / 3	2	S	No	
Pelly Basin													
Pelly	Detour Canyon	YB62	10	9	10	9	8	6	D / 7	0	S	Yes	Also ref. SI75
Pelly	Braden's Canyon	YB62	10	9	10	9	8	4	D / 7	1	S	Yes	Also ref. SI75
Anvil	Anvil Creek	CY68	2	3	0	4	3	4	B / 3	7	U	No	
Tay	Tay	CY68	2	3	6	4	3	4	B / 3	6	U	No	
Earn	Earn	CY68	2	3	0	4	3	3	B / 3	7	U	No	
Ross	Prevost Canyon	CY68	7	8	10	5	7	4	C / 5	1	S	No	Also ref. RP62
Mica	Mica Creek	CY68	2	5	0	4	3	4	B / 3	6	U	No	
Porcupine Basin													
Bell	Bell	PP65	10	8	10	5	3	4	C / 5	2	S	Yes	Also ref. SI75
Porcupine	Porcupine Canyon	PP65	10	8	10	6	1	3	B / 3	3	D	No	
Porcupine	Porcupine Diversion	PP65	10	8	10	4	1	3	B / 3	4	D	No	

TABLE 5-2

Rating of Site Inventory Data and Study Adequacy

Basin/River	Project	Report[1]	Field Work (10)	Rating of Inventory Data and Study Adequacy[2]								Socio-Environ. Study?	Remarks
				Topography (10)	Geotech. (10)	Hydrology (10)	Estimating (10)	Out-Date (10)	Study Level/ Depth (/10)	Number of Deficient Factors (7)	Adequacy Category[3]		
Stewart Basin													
Stewart	Low Fraser Falls	S175	2	8	10	9	3	8	B / 3	3	D	Yes	
Stewart	High Fraser Falls	YB62	10	9	10	7	8	3	D / 7	1	S	Yes	
Stewart	Independence	YB62	10	9	10	8	8	4	D / 7	1	S	Yes	
Stewart	Porcupine	YB62	10	9	10	6	8	4	D / 7	1	S	No	
Stewart	Seven Mile Canyon	CY68	2	3	0	4	3	4	B / 3	7	U	No	
Stewart	Big Kalzas Lake	CY68	2	3	0	4	3	3	B / 3	7	U	No	
Hess	Two Mile Canyon	CY68	2	3	6	4	3	5	B / 3	5	U	No	
Hess	Hess Canyon	CY68	2	3	0	4	3	4	B / 3	7	U	No	
Hess	Rogue	CY68	2	3	0	4	3	3	B / 3	7	U	No	
Pleasant	Pleasant Creek	CY68	2	3	0	4	3	3	B / 3	7	U	No	
Ethel	Ethel Lake Diversion	CY68	2	5	0	4	3	4	B / 3	6	U	No	
Mayo	Mayo B	CY68	2	3	0	6	3	5	B / 3	5	U	No	
Lake	Lake Creek Diversion	CY68	2	5	0	4	3	3	B / 3	6	U	No	
McQuesten	North McQuesten	CY68	2	5	0	4	3	3	B / 3	6	U	No	
White Basin													
White	Upper Canyon	CY68	2	5	0	2	3	3	B / 3	6	U	No	
White	Lower Canyon	CY68	2	8	10	2	3	3	B / 3	5	U	No	
Kluane	Kluane Canyon	KL62	8	8	10	6	7	2	C / 5	1	S	No	Also ref. CY68
Donjek	Donjek	CY68	2	3	0	1	3	2	B / 3	7	U	No	
Lower Yukon Basin													
Sixty Mile	Sixty Mile Diversion	CY68	2	3	0	4	3	3	B / 3	7	U	No	
Forty Mile	Forty Mile	CY68	2	5	0	4	3	3	B / 3	6	U	No	
Fifteen Mile	Fifteen Mile Diversion	CY68	2	3	0	4	3	3	B / 3	7	U	No	
Indian	Indian	CY68	2	5	0	4	3	3	B / 3	6	U	No	

TABLE 5-2

Rating of Site Inventory Data and Study Adequacy

			Rating of Inventory Data and Study Adequacy[2]										
Basin/River	Project	Report[1]	Field Work (10)	Topography (10)	Geotech. (10)	Hydrology (10)	Estimating (10)	Out-Date (10)	Study Level/ Depth (/10)	Number of Deficient Factors (7)	Adequacy Category[3]	Socio-Environ. Study?	Remarks
Yukon Basin													
Yukon	Miles Canyon	YB62	10	9	10	8	8	3	D / 7	1	S	No	
Yukon	Hootalinqua	YB62	10	9	10	7	8	3	D / 7	1	S	No	
Yukon	Big Salmon	YB62	10	9	10	7	8	2	D / 7	1	S	No	
Yukon	Low Five Fingers	SI75	2	8	10	9	3	5	B / 3	4	D	Yes	Also ref. PS66
Yukon	High Five Fingers	YB62	10	9	10	7	8	3	D / 7	1	S	Yes	
Yukon	Wolverine	YB62	10	9	10	6	8	2	D / 7	1	S	Yes	
Yukon	Britannia	YB62	10	9	10	6	8	2	D / 7	1	S	No	
Yukon	Ogilvie	YB62	10	9	10	7	8	2	D / 7	1	S	No	
Yukon	Dawson	YB62	10	9	10	7	8	2	D / 7	1	S	No	
Yukon	Boundary	YB62	10	9	10	6	8	2	D / 7	1	S	No	
Yukon	Yukon-Taiya	YT66	8	7	8	8	8	5	D / 7	0	S	No	
Yukon	Yukon-Taku	YT66	8	7	8	8	8	5	D / 7	0	S	No	
Yukon	Tagish Storage	Unpub.	2	5	6	9	8	7	B / 3	2	S	No	
Teslin	Swift	YB62	10	9	10	7	8	4	D / 7	1	S	No	
Wolf	Wolf	CY68	2	3	0	1	3	3	B / 3	7	U	No	
McNeil	McNeil	CY68	2	3	0	1	3	3	B / 3	7	U	No	
Big Salmon	Quiet Lake/Nisutlin	CY68	2	3	0	1	3	3	B / 3	7	U	No	
Takhini	Primrose/Kusawa	SI75	2	5	0	8	3	6	B / 3	4	D	Yes	Also ref. CY68 YB62
Little Salmon	Little Salmon	MH80	4	7	8	6	4	8	B / 3	3	D	No	
Little Salmon	Drury Lake	CY68	2	3	0	1	3	3	B / 3	7	U	No	

Notes:
[1] Refer to Bibliography, Part 7
[2] Refer to Part 5 of Text, and Table 5-2(a)
[3] Adequacy category:
S: 1 or 2 factors deficient
D: 3 or 4 factors deficient
U: 5 to 7 factors deficient

TABLE 5-2(a)

Derivation of Adequacy Ratings Contained in Table 5-2

Field Work Rating (to a maximum of 10 points) based on duration of site investigation and description of work accomplished.

Topography Rating divided into two components: damsite topography; and reservoir topography. Points (to a maximum of 10) given as follows:

Damsite Topography Available Mapping	Points
- none	0
- 1:250,000 NTS, 500 ft contours	1
- 1:50,000 NTS, 100 ft contours	2
- 25 ft or greater contours from airphotos	3
- 20 ft contours from airphotos	4
- 10 ft contours from airphotos or ground surveys	5

Reservoir Topography Available Mapping	
- none	0
- 1:250,000 NTS, 500 ft contours	2
- 1:50,000 NTS, 100 ft contours	3
- 50 ft form lines on airphotos	4
- better than 50 ft contours from airphotos	5

Geology Points (to a maximum of 10) given as follows:

Geotechnical Appraisal	
- none	0
- site reconnaissance with no subsurface investigation	6
- detailed site mapping with seismic work and test pitting	10

TABLE 5-2(a) (Cont'd)

Hydrology

Rating based on assessment of period of record, location of hydrometric stations, change in flows from the time of the study to the present (outdatedness), and an overall judgement of the adequacy of the work. Points (to a maximum of 10) given as follows:

Period of Record	Points
0-5 years	1
5-10 years	2
10-15 years	3
15-20 years	4
> 20 years	5

Location of Gauging Station	
- [illegible] gauge on river studied	0
- gauge on river, but far from site under consideration	1
- gauge on river, reasonably close to site	2

Outdatedness of Hydrometric Data	
- little or no change (less than about 5%) in record flows from original study to present	3
- some change (about 5-10%) in flows	2
- moderate change (about 10-20%) in flows	1
- large change (> about 20%) in flows	0

It should be noted that judgement is involved in determining the significance of a change in flows. For example, although an increase in the maximum recorded flow would change the design flood and hence spillway capacity, its significance would be considerably less than that of a similar increase in the long-term mean flow, or a decrease in the flow over the critical period which would directly affect the plant output capability and energy cost.

Cost Estimating

Rating based on the degree of detail contained in the estimate (0 to 3 points), whether or not quantities were calculated (0 to 3 points), and an overall assessment of the adequacy of the estimating (0 to 4 points). Total rating to a maximum of 10 points.

TABLE 5-2(a) (Cont'd)

<table>
<tr><td>Study Depth</td><td>Based on the assessment of the level of each study, using the standards described in Part 3, points were given as follows:
<table>
<tr><th colspan="2">Study Level</th><th>Points</th></tr>
<tr><td>Pre-reconnaissance</td><td>Level A</td><td>1</td></tr>
<tr><td>Reconnaissance</td><td>Level B</td><td>3</td></tr>
<tr><td>Inventory</td><td>Level C</td><td>5</td></tr>
<tr><td>Pre-feasibility</td><td>Level D</td><td>7</td></tr>
<tr><td>Pre-feasibility</td><td>Level E</td><td>8</td></tr>
<tr><td>Feasibility</td><td>Level F</td><td>10</td></tr>
</table></td></tr>
<tr><td>Outdate Factor</td><td>Judgement of the degree of correspondence of the conceptual design with current practice, and of relative costs of construction. Includes a negative component for the age of the study. Points from 0 for out-of-date to 10 for up-to-date.</td></tr>
<tr><td>Number of Deficient Factors</td><td>The number of factors with ratings of less than 5 points out of 10.</td></tr>
<tr><td>Adequacy Categories</td><td>S - satisfactory when 1 or 2 deficient factors rectified.
D - deficient - 3 or 4 deficient factors.
U - unsatisfactory - 5 to 7 deficient factors.</td></tr>
</table>

PART 6

CONCLUSIONS AND RECOMMENDATIONS

6.1 CONCLUSIONS AND RECOMMENDATIONS

CONCLUSIONS

Analysis of the information reviewed during this study has confirmed some of the prior assumptions and indicated that other concerns may be of lesser importance than they seemed. The review has revealed in many respects the value of the task, while in others it has discovered where past reports do not provide sufficient detail to allow proper review.

Assessment of the need to apply up-to-date hydroelectric technology was seen as a necessary part of the tasks. However, it became apparent as the study proceeded that for two reasons this would not be fully attainable. Firstly, because at more than half the sites previously studied, sufficient detail of the designs used had not been provided. Secondly, that there was inadequate subsurface information in all but the recently studied sites to evaluate whether modern methods of foundation treatment were appropriate.

Where sufficient information was available to form preliminary appraisals, such as in the 1962 Yukon Basin Study, it was clear that layouts would likely be changed significantly if designed in conformity with current design practice and some reflection of this in the adequacy rating was possible.

Another avenue of intended research was the exploration of the importance of updating comparative construction costs of alternative structures such as earth fill vs concrete dams, canals vs steel or tunnel conduits, etc. Major changes in these costs can change project layouts and so economic attractiveness.

However the estimates given in the reports for many projects do not contain sufficient detail including quantities and unit prices to assess the significance of this assumption. Furthermore the relative escalation of these unit prices for the Yukon area does not seem to be derivable from Statcan indices. Again it was not possible to adequately rate this factor, although in a minor way it is reflected in the adequacy ratings.

With the foregoing qualifications in mind the Review conclusions can be crystallized as follows:

As expected, the inventory was found to be a patchwork of studies to widely differing levels by many authors over a period of more than twenty years. The potential projects studied ranged widely in apparent importance and the ratings were seen to depend on the relative weight given to long term as compared with short/medium term needs. It is significant that despite the very marked discounting of the importance of project size in the ratings, the mega projects were still rated highest overall.

About 60% of the projects listed in Table 5-2 were found to have been studied to less than an adequate level for inventory purposes. The need for updating was seen to be somewhat less important than the need for more detailed study with better input data. The need to relate hydro development of rivers to socio-environmental impacts and adapt projects to minimize negative effects and provide mitigation measures, was found to be a most urgent need for all the older studies. Since these cover more than 75% of the total resource potential (excluding Yukon-Taiya/Taku), it follows that this potential cannot be known until such work is accomplished.

It was determined that the findings of the few recent studies confirmed those of earlier studies for less than half the sites. This comparison also suggested that some, perhaps many, attractive sites have not yet been identified or studied.

In somewhat more detail the conclusions can best be examined by considering the three groups of projects 1, 2 and 3 described earlier in Section 5.

Group 1

The mega project group studied in the early to mid 1960's is found to be made up of sites of major importance to the Basin. The projects are economically attractive, more so in the south than in the north. The studies were carried out by the Water Resources Branch over a period of years and were adequate at that time to provide a satisfactory inventory.

It is now seen that revision and updating of these studies is required chiefly in two respects. Firstly the major problem is that socio-environmental concerns were not addressed and hydro development was studied for maximum power on the subject rivers without modification to reflect socio-environmental concerns. Studies examine one possible scheme of development, indicating that other schemes are not ruled out and may be found attractive on further study.

Secondly an examination of the layouts devised for many of the mega projects reveals that depending on a better knowledge of bedrock levels, modern practice would favour abutment spillways excavated in rock, rock fill dam sections increased, concrete dam sections reduced, and with fewer and larger gates and generating units. These changes should make for lower capital costs.

The projects in this group comprise about 75% of the total Basin potential and significant development modification to meet socio-environmental factors will almost certainly result in accompanying reduction in power potential.

Accordingly, for long range planning purposes there is a priority for revising development plans incorporated in these reports based on the necessary appropriate environmental studies, and modern hydro design practice. For short to medium term needs, there is less urgency, particularly for northern and larger sites which are less likely to be required for many years.

Updating of estimates and hydrology are other areas which should receive attention.

Group 2

Sites, primarily studied between 1968 and 1978 include some 40 projects of varying sizes, chiefly of medium to small capacity located in central Yukon where suitable loads may develop in the not too distant future. Some of these therefore achieve an importance rating not justified by their modest size. This group however have generally not been studied to a level where layouts can be accepted with confidence, except for those sites having adequate input data from previous studies, since they have generally inadequate field investigations, topography and geotechnical data. Hydrology is adequate for some sites and inadequate or outdated for others. Estimates are generally not in sufficient detail for confident acceptance.

Only about one quarter of this group of projects have had an environmental overview (Ref. SI75), and this not to a level where comparative ranking was deemed appropriate.

Group 3

The third group of studies which were carried out within the last five years are generally to inventory or pre-feasibility level, do not require updating, and can be accepted as reliable. There are however some gaps in the input data which should be filled, in particular, subsurface information, reservoir topography and clearing areas, clearing standards and costs for the Hoole Canyon and False Canyon sites. The Slate Rapids site, presently at Inventory level, should be brought to Level D.

The foregoing indicates that virtually all the Group 1 and Group 2 site studies have some outdated or inadequate factors requiring revision, updating or reworking. A relatively small amount of work will bring the Group 3 studies to a uniform and adequate pre-feasibility level.

It was concluded generally that the best use of Tables 5-1 and 5-2 would be to examine the rating of the separate "Importance" and "Adequacy" factors for any sites under consideration, rather than rely on the combined ratings for such sites.

The combined ratings reflect subjective differences in factor weighting which will almost certainly change with time. These in turn would change the combined site importance ratings.

In the adequacy ratings a favourable combined rating can hide a serious deficiency of one critical factor as a result of high marks for several other factors.

At the best, the combined ratings provide a very rough guide. They do suggest at this time that the Primrose/Kusawa scheme warrants further consideration, as does the Kluane Canyon site. The Bates/Tatshenshini sites would also be priority investigations if the Kluane Park, Indian land claims, and salmon fisheries problems could be resolved. The Anvil and Tay schemes are well located for any load expansion in the Faro area, and might be found to have some promise. Another group of sites flagged as of average importance and deficient in study adequacy are those in the southeast corner of Yukon on the Beaver and Coal Rivers.

RECOMMENDATIONS

The basic recommendation to bring the inventory to an adequate level of study and reliability by a phased program spread over perhaps 5 to 10 years and designed to give priority to the more important sites and those most in need of revision and updating.

The program suggested by this review would depend on the balance between the emphasis placed on long term planning as compared with the more imminent needs for power in the short/medium term. It is anticipated that this emphasis will change depending on the current views of decision makers.

Long Term Planning

The priority would be directed primarily to mega project Group 1, particularly sites on the Yukon River and would include:

a) Re-examine unstudied sites and search for unidentified sites;
b) Carry out socio-environmental overview;
c) Adjust river development schemes based on a) and b) with impacts minimized and mitigation costs included;
d) Revise studies to include design layouts based on current practice, up to date hydrometric records, and detailed estimates;
e) Revised studies to include geotechnical assessment with a few drill holes to verify seismic work.

This program would provide reliable inventory or pre-feasibility level reports for attractive sites with a minimum of new field investigation. The order in which sites would be examined would be based on the ratings of importance and adequacy given in Tables 5-1 and 5-2 amended by current prediction of major loads. Zone 1 sites are presently seen as likely to be needed earliest, with priority decreasing through Zone 2 to Zone 3.

Relatively unimportant or unpromising sites could have studies terminated at Inventory level C.

Short to Medium Term Requirements

This program would essentially continue the work carried out by NCPC over the last few years on promising Zone 1 sites in order to:

1) study to pre-feasibility level a selected group of sites ranging from small to large in areas with the highest probability of early load development.

2) study to level C or D as appropriate sites adjacent to attractive sites allowing a development plan to be examined for the subject river.

3) commission a socio-environmental overview for these sites.

4) revise and update studies of Group 2 sites to Inventory level C with priority for more important sites and those most requiring revision and updating as noted in Tables 5-1 and 5-2.

5) search for undiscovered or unstudied (Table 4-3) medium and small project sites in Zone 1 later extended to Zone 2. Promising sites to be studied to Inventory level C.

As a priority the Slate Rapids project on the Upper Pelly River, so far studied barely to Inventory level, should be investigated to pre-feasibility level since it may be the site most suited to early development. The complementary Hoole Canyon project pre-feasibility studies require minor upgrading. Early study of the Hoole River site lying between these will be necessary for optimum river development.

Study Criteria

It is assumed that the above program will be carried out by different agencies, departments and consultants. It is seen as most important that the results of these studies allow proper comparisons between projects and provide a consistent inventory. It is therefore necessary that standard design and costing criteria be used and also as far as possible a similar report format. This course was adopted for the recent pre-feasibility studies of the Hoole, Ross, and False Canyon schemes which were carried out by different engineering consultants. It included design criteria covering spillway and diversion capacities, dam freeboard, clearing standards, capacity factor, unit size, etc. Also covered were financial and estimating criteria such as interest rate, unit costs of major construction items, camp costs, escalation, contingencies, etc.

Adequate time and funding is most important and it is recommended that a program studying fewer sites to an adequate level is preferable to a relatively superficial multi-site study.

Since the program will extend over several years and later updating and upgrading to a higher level investigation will be required in some cases, it is essential that full back-up data be provided in report appendices. This should include such data as design assumptions and criteria, a detailed estimate and estimating criteria, topography including manuscripts from aerial photography, details of site investigations including survey information, photographs, diaries, etc. Also, photo interpretation overlays should be provided and of course drill hole logs and seismic results.

PART 7

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Study	Designation
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APPENDIX A

TERMS OF REFERENCE

THE CONSULTANT SERVICES - SECTION "C"

This document is the document referred to as Section "C" The Consultant Services and referred to in Article V of the Consultant Agreement entered into on the 10th day of January, 1983 between the Commission and the Consultant.

The Consultant shall, in a manner satisfactory to the Commission's Representative, perform the following services:

1. TITLE

Yukon Hydroelectric Sites Inventory Review

2. TERMS OF REFERENCE

One of the aims of the current Yukon River Basin Study is to set in proper perspective the hydroelectric potential of the Basin, including its development and management. However, it has been pointed out that much of the available information on the hydroelectric potential of the Basin is outdated.

The existing inventory studies are the 1963 Water Resources Branch - Hydro Power Resources of the Yukon, the 1968 Ingledow-Survey of Central Yukon, and the 1975, Sigma - Power in the Yukon. There are in addition a number of studies which cover single sites or areas containing a few sites each.

Virtually the only subsurface investigations for all these studies was a limited seismic program for the major sites of the Water Resources Branch 1963 study. No drilling was carried out for any study. All studies are handicapped by incomplete 1 in 50,000 NTS Mapping.

Some of the more recent individual site reports, Mid-Yukon, Granite Canyon, False Canyon, etc., have been brought to a pre-feasibility level with limited drilling. However, to date only seven sites fall into this category.

The Consultant's study is for a review to indicate the priorities for revision and updating the existing inventory.

3. PURPOSE

The study will assess the adequacy of Yukon's existing hydroelectric inventory in light of update construction costs, improved and modified dam technology, a hydrological record of much greater extent and detail than was available for earlier inventory studies, and recognition of socio-environmental factors.

4. SCOPE OF WORK

(1) Review all previous studies with the purpose of determining the degree to which revision and updating is necessary and urgent. No field visits would be possible under the budget.

(2) Review will consider for inventory sites:

- (a) hydrology using recent flow measurement data
- (b) changes in relative costs of material and structure since previous studies
- (c) accuracy and reliability of input data including maps, topography, geotechnical information, etc.
- (d) socio-environmental factors
- (e) layout of schemes based on any changes in (a) to (d).

It is recognized that there will be a major subjective judgement element in this review.

(3) Rank sites in importance based on project size, location relative to potential loads, apparent economic attractiveness, etc. modified by any changes indicated by the review described in (2).

(4) Prepare a selected list of sites deserving early review, updating, and study to pre-feasibility level.

(5) Prepare a brief report section documenting the work carried out.

5. GEOGRAPHIC LIMITS

The study will consider all sites in Yukon (about 95 sites), whether within the Yukon River Basin or not. It will also include the Yukon-Taiya and Yukon-Taku schemes which are major diversions out of the Basin involving Alaska and British Columbia. The study will incorporate preliminary inventory work now underway at B.C. Hydro for the B.C. portion of the Yukon River Basin.

6. SCHEDULE

The review is to be completed and a final report prepared by June 30, 1983.

7. FINAL REPORTS

The Consultant will deliver thirty seven (37) copies of his final report, including appendices, to the Commission's Edmonton office within 30 days of completion of the requirement of this Agreement.

APPENDIX B

ENERGY RESOURCES OF NORTHERN CANADA: HYDRO

by W.J. Smith

SEVENTH NATIONAL NORTHERN DEVELOPMENT CONFERENCE

NOVEMBER 3, 4, 5 1976
EDMONTON, ALBERTA

PANEL II

ENERGY RESOURCES OF NORTHERN CANADA

HYDRO

W.J. SMITH, ENG

MONTREAL ENGINEERING COMPANY, LIMITED

PANEL II

ENERGY RESOURCES OF NORTHERN CANADA

HYDRO

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- *Served as lieutenant in RCN VR on loan to Royal Navy to 1945.*
- *Joined Montreal Engineering Company Limited in 1946 and worked continuously for that Company to present date mainly in the power utility field.*
- *Work has included hydro, conventional thermal and nuclear projects and studies in Canada, India, Pakistan, Singapore, Sri Lanka, Indonesia, Nigeria, Central and South America.*
- *Main involvement prior to 1960 was in the hydro electric field and early projects included several in Northern Canada such as Snare, Mayo, Whitehorse and Menihek.*
- *Now Group Vice-President for Montreal Engineering Company Limited responsible for work in the hydro and thermal divisions for domestic and overseas work.*
- *Chairman of Canatom Ltd.*
- *Director of Monenco Limited, Montreal Engineering Company Limited and several subsidiary companies.*

INTRODUCTION

The subject which has been assigned to me in this Conference is a very large one which must be restricted to some degree to be covered in a single paper. Your Program Committee suggested that I cover three principal items:

1. The potential locations and indicated capacity for hydro development.
2. The conditions under which and the prices at which hydro development might be economical.
3. The importance and the problems of transmission systems, particularly as they affect the economics of remote generation sites.

These points are covered in the first part of my address. In addition, I thought it would be of interest to highlight some areas of concern in the matter of planning future hydro development and have taken the liberty of reviewing some of these factors in the second part of this paper.

I am sure that this audience and my colleagues on the panel will agree that in the short time available, this subject cannot be presented or debated with any degree of precision. My approach, therefore, is to make some major assumptions for simplification of the information and thereby hopefully focus on the subject sufficiently well to facilitate a meaningful discussion by the panel. I would, therefore, ask your indulgence in accepting my basic assumptions, none of which will be right for all particular situations but hopefully they will represent an average situation.

DEFINITION OF THE CANADIAN NORTH

I have noted in previous papers a certain amount of licence in defining "Northern". One paper on contracting in the Canadian North spoke about the permafrost line as a southern boundary. This is obviously of interest to constructors and designers of structures. It is interesting to speculate on the effect on the development of Canada, if it had been used as a northern boundary of our provinces instead of the 60th parallel. For example, you can see from Figure 4 the effect it would have had on the distribution of hydro and other resources between the provinces and the territories.

However, since power resources are so rigidly and zealously guarded by our various Provinces and Territories, I decided the safest course was to include only the Yukon and Northwest Territories in the Canadian North for purposes of this paper. Information on the bordering northern regions of the provinces is available from the utilities in those provinces.

SUMMARY OF HYDRO RESOURCES

It is generally considered that the Yukon and Northwest Territories contain a vast amount of hydro power. To date, very little of this has been tapped. In the Yukon, we have four sites — Whitehorse Rapids, Fish Lake, Mayo and Aishihik, comprising a total installed capacity of 56,000 KW. In the Northwest Territories, hydro power developments exist on the Snare and Taltson Rivers with a total installed capacity of about 49,000 KW. Numerous small thermal plants serve the power needs of the remainder of the areas.

Hydro power is the product of the available streamflow and the hydraulic head. Streamflow is highest in those streams draining the mountains between the Yukon and Northwest Territories, is lowest in the central Northwest Territories and the Arctic Islands and increases again in the region of Hudson Bay. Exceptionally high runoff conditions are found in the southwestern corner of the Yukon where streamflow is affected by melting glaciers and the coastal precipitation.

Streamflow runoff in the Canadian North is generally low compared to rivers in the lower latitudes of Canada. For example, the average flow per square mile of the drainage basin of the Columbia River at the International boundary is more than double that of the Yukon River at Dawson.

Because of the long cold winters with precipitation occurring as snow rather than rain, large storage volumes are required to even out the streamflow over the year to provide a firm continuous power supply. As a result of glaciation there are numerous lakes in the Northwest Territories and in the headwaters of the Yukon River in the Yukon Territory. In many cases, these lakes naturally provide a good degree of streamflow regulation. An excellent example is the Great Bear River where the Great Bear Lake naturally regulates the streamflow to the degree that the six month low flow average is 17,400 cfs while the annual average is 19,980 cfs. These data contrast with similar figures for the Porcupine River at Old Crow with 850 and 12,600 cfs respectively. Often additional storage can be provided by relatively low dams at the lake outlets.

In the preparation of the hydro resources summarized in Table 1, a review was made of existing reports along with summaries kindly provided by the Ministry of Energy, Mines and Resources in Ottawa. This review revealed that a considerable amount of work has been done to quantify the hydro resources but very little of a pre-investment calibre. The majority of the power estimates have been made using maps and stream flows existing at the time the work was done. With the exception of the Yukon where considerable coverage of 1 : 50,000 scale, 50 foot contour maps are available, the existing maps are at a scale of 1:250,000 with contour intervals varying from 100 to 500 feet and therefore it has been virtually impossible to prepare an accurate hydro power inventory. More detailed mapping is necessary for the definition of particular sites and for the preparation of cost estimates. In addition, streamflow data has been scarce or nonexistent in large areas, hence necessitating extensive data extrapolations.

In recent years, there have been a number of new stream flow gauging stations established in the North. Hence, we now have a much better data base than, say, about 5 years ago.

The studies made to date have been categorized in three levels and listed in Table 1.

In order to present to this meeting information on resources which would show regional potential on a relative basis, I have also shown in Table I and on Figure 1, the theoretical potentials. We have made estimates of the theoretical hydro power of the major rivers in the Northwest Territories. The theoretical estimate of the Yukon River is based primarily on the paper by H.T. Ramsden presented to the Northern Resources Conference, Whitehorse on the 22nd March, 1963. Estimates of the resources on the major tributaries of the Yukon River and other rivers were based on the latest streamflow and topographic maps available and great accuracy is not claimed for the result. Similarly, in the Northwest Territories, the hydraulic head available on the major streams was measured from available maps; the streamflows were estimated utilizing data to the end of 1975; judgments made on the degree of regulation available; and the theoretical power potential computed. When additional streamflow and more detailed maps become available, it will be interesting to compare the results. Factors which could modify the present estimates of power that could be developed, are ecological considerations, available streamflows, hydraulic head available and the cost. Many of the small streams with a potential less than 50 MW were not included in the inventory.

You can see that of the total theoretical potential only 0.4% has been constructed to date. Of the total potential under 3% has been studied to a pre-feasibility level (Level 3).

I should add that for simplification, the appraisal of resources is based on development within the present natural watersheds. Hence, diversions such as the Yukon — Taiya and the Yukon — Taku have been excluded and to this extent, understated.

It is also of interest to note that of the total undeveloped hydro resources in Canada, about 30% exist in the Yukon and the Northwest Territories.

ECONOMY OF DEVELOPMENT

In order to focus your attention on the cost at which hydro development might be economical, I have included Figure 2 which highlights the basic factors to be considered. The only practical alternatives to hydro development in the Canadian North in the near future are, of course, fossil fuel thermal stations. Perhaps we will hear otherwise today from the speakers on other forms of energy, but in order to keep it simple, from a cost point of view, let us look at the comparison with the conventional thermal stations for which we have current information on costs. We can assume nuclear power stations would not be a practical or economic answer unless industries were developed requiring large amounts of base load power.

Generally speaking, hydro stations will have a significantly higher initial cost per kilowatt than conventional thermal stations. The latter will have an infinitely higher cost for fuel since water is still free in this part of the world. The two main factors in making a comparison are the financing charges of capital cost and the forecast of the cost of fuel for the thermal stations over the life of the plant. The capacity factor is of particular importance in the hydro stations with zero cost fuel. For this analysis, 50% annual capacity factor has been used. The other factor which has a distinct bearing on the comparison of hydro and thermal is the life of the plant. In utility work, this has normally been taken as 50 years for hydro and 25 years for thermal.

This has the effect of being able to justify a higher investment cost for a hydro plant, particularly if there were no limit on the amount of money to be raised. However, there is a real limit on available capital and some hydro projects which have been justified economically on paper cannot be built simply because of the very large amounts of capital which have to be found.

I would like to particularly emphasize this point since outside of utility work there are few evaluations made on projects with a 50 year plant life. This is a real number for hydro stations as proven by many existing installations and with the improved materials available today, it is considered a conservative figure. However, in addition to the problem of raising more capital for a hydro station, there is the associated problem of cash flow in the early years of its life. This is a point which is often overlooked in projects dependent on short term borrowing.

The very simple chart (Figure 2), shows the cost per kW hour for various capital cost hydro stations and for oil fired thermal stations for varying escalation rates on oil price. Taking a real broad brush approach and mainly to give a ball park number to help us in our discussions, the following numbers are of interest.

An oil fired thermal plant with capital cost of $400 per kW, with a 25 year plant life and with no escalation on fuel costs, would compare with a hydro plant costing $1,500 per kW with a 50 year plant life both operating at 50% capacity factor.

These numbers obviously vary considerably with size factor and the choice of the parameters. They can be adjusted for alternative conditions to suit a particular case. However, I hope the illustration will serve as a basis for an answer to questions posed by your committee on the relative economics of hydro stations. Recent installations and studies would indicate that the 1976 cost of hydro stations, excluding transmission, are approximately:

Small size (50 MW range)	$1,400 to $2,100 per kW
Medium size (150 MW range)	$1,000 to $1,600 per kW
Large size (300 MW up) at best sites	$ 750 to $1,250 per kW

There are obviously many other factors which have to be evaluated in any particular case. The related cost of transmission lines which are discussed separately is obviously an important one since, generally speaking, thermal stations can be built closer to the load center than hydro stations. Then there are the costs of meeting other related requirements such as water transport (present and future), commercial forests, agricultural use, fisheries (commercial and sport), riparian habitat, wildlife, historic and archeological sites, and recreational facilities.

A point that is usually of great concern, particularly for isolated plants, is security of power. Perhaps this is the most serious of all aspects of design when life depends on availability of power as it often does in the frozen north. In this respect, hydro power has served man very well and with due deference to my friends in the thermal design field, I would judge that hydro stations are the most reliable source of power which we have today. This assumes, of course, that adequate precautions are taken, particularly regarding ice problems wherever they occur in reservoirs, intakes, spillways, penstocks, surge tanks, etc. Shutdowns have to be planned for all types of plants but the hydro plant has more flexibility and less risk of serious damage to mechanical equipment if normal running times are exceeded. Because of the higher availability of hydro units, one can expect to have a larger allowance for reserve in a thermal plant. This is a definite cost factor. Another factor which is important is that concerning the operational staff. Hydro plant operation is considerably simpler and requires a smaller staff. Also, the technical skills are more available than those for modern thermal stations. This is an important consideration when a new community has to be developed not only for the power stations but for whatever industrial development is planned.

From a security point of view, perhaps the greatest satisfaction can be derived from the availability of fuel for hydro plant versus thermal plant. For most stations contemplated in the north, fuel supply would be dependent on transport with the attendant labour problems not only in the transport field but in the refineries, mines, etc. Evaluation of this factor is difficult but it certainly would be a plus for hydro.

TRANSMISSION

As mentioned in the preceding discussion, transmission to date has been restricted to those lines connecting hydro plants to the load centres they serve. The paucity of transmission lines in the north relative to the provinces in the south is illustrated on Figure No. 3. It can be seen also how isolated the systems are. The distances are too great to justify economic interconnections at the present time.

Three of the systems have long lines relative to the size of the generating plants which have added to the initial cost of the system, and also produced technical problems such as charging of the line with a relatively small generator and limitations on the size of a motor that can be used at the load end.

Transmission lines, by their electrical characteristics, have limitations in carrying capacity and charging requirements at different voltages, varying from about 25 MW at 69 kV to 260 MW at 230 kV. Costs will vary approximately in proportion to the voltage.

Costs in the north are considerably higher than in the provinces due to lack of access. In each case the engineer has endeavoured to find methods and materials that would keep the costs down. One good example of this is on the Taltson to Pine Point Line, where studies showed that a light aluminum structure in the shape of a Y was the most economical. Access to one section of the line was very difficult, which resulted in a definite advantage to the use of light towers and helicopters for erection. The operation proved so successful that the entire 122 miles of line were constructed by helicopter, including the stringing of the conductors.

Looking to the future, Figure No. 3 illustrates the possible future network of lines that might develop over the next 30 years, in conjunction with hydro projects and gas/oil pipelines. However, the technical problems related to the large distances involved would require adequate studies, along with their economic justification.

One possible development which could result in hydro power growth in Northern Canada is to supply power associated with the operation of oil and gas pipe lines. Since there are so many alternative pipe line projects being studied, I decided to show the proposed gas pipe lines on one map (Figure 4) which indicates hydro sites that could be developed for each of the alternatives. If the Great Bear hydro development were needed, one could then see the development of a transmission line from Inuvik to Hay River and the Yellowknife district. In this respect, we should make sure that recognition is given to the added economies in power supplies to those communities currently using higher priced oil fired thermal power with full standby capacity installed. It is important that we do not isolate such studies and miss the evaluation of side benefits.

The development of high voltage direct current transmission in recent years, provides an economical method of trasmitting large blocks of power over great distances without the inherent technical problems associated with alternating voltage. This has been successfully used in Manitoba, where the northern generating plants are being developed. Some of the large hydro sites could be developed on the basis of selling the energy to the provinces, a good example of this being the Baker River on the west coast of Hudson Bay.

PLANNING

Now having presented the basic information related to inventory, cost and transmission, as the first part of my address, I would now like to make a few points relative to our attitudes to power development in the North. I have mentioned that it would be wrong to take statistics such as given in this paper and try to pick the next most likely spot for development of power or, alternatively, the best area for development of industry, mining or other planned growth. Most utilities like to keep an inventory of their options for power installation growth so that when industry develops a need for power, the utility can respond with a good indication of a means of meeting the power requirement.

In the past, some industries have developed their own power for their northern developments such as the Menihek Development in Labrador, Hart Jaune Development in Quebec, Kitimat in B.C. and Island Falls in Manitoba. These were developed largely without much background information on river flows, flood designs and, in particular, without any long term planning relative to environmental aspects.I would suggest that this conference should seriously consider ways in which encouragement could be given to long term planning through adequate studies of our resources. Here again, I would like to emphasize that the evident lack of available good information for the preparation of this paper should be of serious concern to all those interested in the development of our North. I have been rather impressed in some of my international work where lending agencies will provide funds of an order of magnitude ten times or more what has been spent on our Northern resource hydro studies for comparable size of region. This, of course, is the type of study which includes exploratory drilling at certain sites in order to give some accurate information on the feasibility of constructing dams and reservoirs. If we are going to property plan our affairs and be able to take action when requirements for power suddenly become known, we will have to do more exploratory work. To help our discussion, I would like to call your attention to some aspects of developing an adequate inventory.

EXPLORING THE HYDRO POWER POTENTIAL OF THE NORTH

While we can calculate the theoretical hydro power potential of a watershed or of a whole territory, we know that a significant part of this cannot be developed for reasons of engineering impracticality, lack of storage sites or economic viability.

An inventory study of the area permits the realistic part of the potential to be identified separately from the impractical part and allows the most favourable sites to be investigated, estimated and ranked in order of cost. This is the first step in planning which leads to final selection, design and construction of the most suitable scheme to meet the current load growth. Without it, the wrong choice may be made and precious lead time wasted in the selection process. Such a mistake could burden society with additional power costs of millions of dollars each year, perhaps through selection of a more costly hydro alternative or a plant utilizing nonrenewable resources such as oil, gas, or coal.

In recent years, initiation of a new hydro power scheme has depended on satisfying regulatory bodies that the scheme is the optimum for society in general, both with regard to safety and economic viability, and also in respect to environmental and social concerns. These concerns have reinforced the need for careful inventory studies, since the negotiations necessary to rationalize environmental problems often result in significant increases in construction time and cost. The inventory should rank alternatives from an environmental viewpoint, so that ultimate selection can be demonstrated to be the best compromise considering all interests. The lead time for a medium sized hydro project from selection to power production is now about five years. Since the resource based or industrial project which requires this power can often be completed in less than this period, the importance of adequate inventory studies early enough is clear, so that the much needed industry will be encouraged rather than discouraged by the power supply situation.

Unfortunately, the cost of inventory studies has been increasing rapidly with the incorporation of environmental and socio-economic studies, and such expensive services as aerial photography, helicopter reconnaissance and often drilling.

From work which my Company has carried out on many studies overseas in addition to investigation work in Canada, I have found that prefeasibility studies may be expected to range in cost from $50,000 to $150,000 and feasibility studies from $250,000 to over $2 million. The great differences in plant size and complexity of site and foundation conditions accounts for the wide range of costs.

This raises the question of whether a more superficial study will suffice with consequent saving in cost. Unfortunately, there are real dangers in this course of action, with necessary assumptions untested, subsurface conditions unknown, and possibly without sufficiently close examination, a major potential may be overlooked. Furthermore, the study once published is normally accepted as substantially adequate, and sites with undiscovered potential are not re-examined.

An example of this is the assessment of the potential of the Great Bear River in the Northwest Territories. This river was shown in a Water Power Resource Inventory Sheet in 1965 to have a potential of less than 32 MW. Subsequently, in a pre-inventory study of part of the Territories, the potential was rated between 190 MW and 350 MW. A prefeasibility study with extensive field work recently carried out by the Northern Canada Power Commission revealed that 600 MW capacity could be developed. This information has been used in making an assessment of the use of hydro power for operating the pumping stations in the proposed MacKenzie Valley Pipeline. A good inventory of this hydro resource could have avoided a possible oversight of this alternative source of power.

There is no short cut or low cost solution to hydro power investigation. In the field of oil exploration, there is no substitute for drilling holes many of which may be dry ones. While hydro investigation is less costly than the deep drilling required to prove oil or gas reserves, it is not cheap, and many sites investigated will not be economic. It should be noted, however, that the cost of an adequate inventory of hydro power resources expressed in terms of "per kW of generating capacity found", is in fact quite trifling. In our Brazilian studies in the sixties, it amounted to only 17c kW capacity or less than 0.1% of the estimated capital cost of the developments. These studies consisted of an inventory of hydro resources and feasibility studies of the more attractive sites. Today's cost per kW would be higher although the percentage of estimated capital cost may be similar; it is a small price to pay for the invaluable help in proper planning of the best use of our resources.

The problem of paying for these necessary studies is most acute in the North with its huge area and myriad rivers, with a total population of only a medium sized town in southern terms. How can such a small group of power consumers finance an inventory of so vast an area? This problem must be worked out between the Federal and Territorial Governments and I believe should not be a burden on northern consumers alone. However, the direction of such studies and areas of priority should be in the hands of the utility, which is in the best position to predict future requirements.

There is one way to alleviate the immediate need for financing a comprehensive study program. In the North, at present, the load centres are small, few, and often remote from much of the hydro potential. This is particularly the case in the Northwest Territories. Accordingly, it is hard to justify early expenditures on studies very remote from present and expected load centres while closer sites have not been investigated.

Such remote sites may not be required for decades under normal rates of load growth. It seems reasonable, therefore, that the inventory should proceed by stages, over perhaps a ten-year period, centred first in the zone containing present and expected load centres and then, in perhaps two more stages, in zones expanded to include progressively the more remote sites.

There is some risk in this strategy, since major increases in power demand tend to be for the mining industry and may be located in places which cannot be foreseen. Until the inventory is completed, delay due to uncertainty as to the availability and cost of power must be anticipated. However, these risks might be accepted if the necessary funding must be staged over a period of years.

Since the environmental and social concerns have such a large bearing on the development of hydro power, I would like to propose a slightly different approach to this aspect of hydro projects in the nature of environmental enhancement.

OPPORTUNITIES FOR ENVIRONMENTAL ENHANCEMENT

Hydroelectric developments have fallen from favor with the North American public in recent years. The news media have generally sided with environmental groups in criticizing hydro development as a rape of the scenery and habitat. No doubt some of their criticism has been justified by lack of consideration for non-power concerns and interests in past development. However, there is no merit in society, while attempting to blame those responsible for past omissions, inflicting on itself penalties in the form of delays and crippling costs.

It should be recognized that the battle for reasonable treatment for environmental concerns has been won. Reservoirs are to be adequately cleared, migrating fish passes provided, navigation and recreation interests protected, and communities properly considered in development plans. Environmental impact studies are being produced in unprecedented volume, although not surprisingly, they are not providing all the answers as to what should be done, but tending to say what should not be done.

With difficult decisions required to resolve conflicts between power and the environment, it is tempting for regulatory bodies to delay such decisions and the initiation of developments. Such delays can involve in some cases several years and enormously increased costs due to inflation, crash programs and provision of interim alternative power facilities.

It is worth noting at this point that in many other parts of the world these problems are treated both by the public and authorities in a more rational and less emotional manner. In most of Europe and in much of the developing world, hydro power is still regarded as a desirable resource development. In the one case perhaps because Europeans have developed more wisely in the past, paying due regard to all impacts of their projects and in the other because developing countries have such an urgent and overpowering need for power and development. But that is not the full story, for it seems that by choosing to resolve conflicts between power and the environment by the traditional adversary process, we have polarized the opposing views and increased substantially the problems of finding the appropriate compromise.

I feel that these problems can best be worked out by interdisciplinary teams sitting down together, appreciating each other's viewpoint, and producing acceptable compromises, rather than setting up a court room process where antagonism reigns. Indeed with present processes, with the energy of all participants absorbed in head-on clashes which usually produce little more than a stand-off, we seem to have forgotten to look for the positive attributes in projects and it may well be that the important opportunities are being overlooked.

Now, let it be clear that while the media appear to be telling the public that they can have their cake and eat it too in the power/environment problem, there is no question that some changes and damage to the development areas are inevitable with many hydro projects. Fish passage may be interfered with, spawning beds flooded, forest and agricultural land lost under reservoir water and siltation and river flows altered.

However, there are ways in which undesirable impacts may be reduced and mitigated, and there are compensative and enhancing measures which may be taken.

Furthermore, some of the changes can be beneficial, including increased winter river flows benefitting all users, flood control by storage reservoirs, addition of a tourist attraction, a new lake for recreational purposes, and improvement in water temperatures for fish habitat, and perhaps many others.

In many, perhaps most, hydro developments, there is the potential for environmental and social enhancement which may more than offset the negative environmental impact. I suggest that a positive Environmental Enhancement Study will be found worthwhile as an offsetting factor to the basic impact study. Such an enhancement and mitigation study should be carried out in my view by a different group from those responsible for the impact study although in closest cooperation with them. The reason for this is that the basic environmental study first deals with the way things are before the power development and then the changes which the project can be expected to make. Often the existing conditions are seen as the ideal, "You can't improve on nature" and every change is seen to be detrimental. The enhancement study however is philosophically oriented in the other direction; that is, the habitat and the environment can be in some instances improved for the good of society. Those participating in such a study must be so oriented, and knowledgeable not only in sciences such as biology, forestry, etc., but in the many ways that have been used across the world to improve existing conditions.

The Enhancement Report would, together with the Project Feasibility Report, represent the total development measures proposed to benefit society to the maximum.

Again, in order to minimize delays in starting a new project in response to a new power demand, inventory studies must stress the environmental aspects in order to ensure that restraints are not prohibitive and, alternatively, that enhancement of the environment can outweigh any detrimental concern.

NORTHERN CONSTRUCTION, LOCAL MATERIALS AND THE ENVIRONMENT

Elsewhere at this conference the problems and high costs of transportation in the North are being examined. The advantages of using such local materials as earth and rock fill instead of concrete made with cement imported from the South is apparent and need not be stressed. However, there are further advantages in the use of local materials which are not as readily seen and these may fit into protection of the environment, unlikely as it may seem.

To illustrate this, I will use an example from our Northern experience, the storage dam and control structure on Nonacho Lake north of Fort Smith in the Northwest Territories. But first let me return to the environmental aspect mentioned.

One major criticism of hydro developments has been that the necessary storage reservoirs flood terrain with consequent damage. Even when shorelines are cleared, the raised levels on the lake are thought to be a major disruption and change. In some cases this impact may be reduced by cutting down the lake outlet. Another possibility is to use a smaller storage level increase on two or more lakes rather than to pile it high on a single lake in the system. In some cases it may thus be possible to stay within, or only slightly in excess of the natural historic range of lake levels. This latter arrangement is naturally more expensive in most cases, since it requires more control structures and access roads to them. Accordingly, low cost designs for such small storage dams must be developed and methods of constructing and operating them effectively developed without the necessity of constructing and maintaining costly isolated access roads, remembering that such roads are often seen as environmental problems in themselves.

In the case of the Nonacho Lake structure, the prime consideration was the high cost of a conventional concrete structure and of about 150 miles of access road across impossible terrain with innumerable lakes, bogs and bedrock. The solution was to forget construction of even a winter access road and to construct and operate the structure using air transportation. Construction without road access was possible by using a Hercules aircraft landing on lake ice reinforced by flooding, to bring in portable camp buildings, bulldozers, loaders and supplies. The construction was compressed into a 2½ month period, January - March, and had to be complete before thawing of the airstrip so that camp and equipment could be airlifted out. The structures were designed so that cold weather construction without the usual heated enclosure would be possible. Rockfill dam, spillway excavated in rock, and a treated timber control structure were utilized. The dam was designed without an earth core which could not have been borrowed or placed in the winter. Two sizes of rock formed a "leaky" rockfill adequate to perform the regulation function, since some flow was necessary in the lower river even when storing in the lake.

Access for operation of the control gates is by float plane normally on a twice per year basis.

Costs of this project were less than one third of a conventionally designed and constructed dam, and operation has been satisfactory.

The Nonacho type of dam without costly access roads may be the answer to some storage problems with their associated environmental impacts. Another low cost example is the recently completed Marsh Lake Dam near Whitehorse on the Yukon River where a steel pile structure using local rock for an anti-erosion blanket cost less than half the originally proposed concrete structure, and was completed in about half the time. Another is the Mayo Lake storage dam in central Yukon, which is now 25 years old, built on permafrost terrain of local timber cribwork with rock and earth fill.

The problems of design and construction in the North are really not as extreme as they have sometimes been presented. Most of them are experienced in southern Canada where similar severe winter conditions often occur. For example, problems such as frazil ice in rivers, freeze-thaw deterioration of concrete, maintaining schedules through winter seasons, maintaining an effective construction force in isolated locations, etc., are mostly the same but somewhat more severe in the North. Some are however unique: permafrost foundations, lack of daylight in winter, and long and difficult transportation routes with associated high costs and sometimes only seasonal access.

Innovation and use of local materials have been the means of making economically viable hydro power possible in some northern locations.

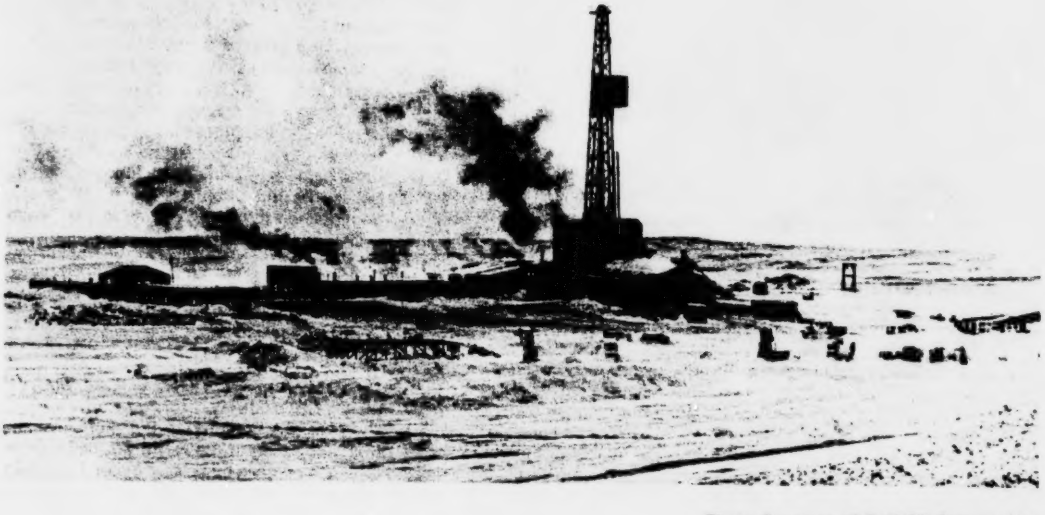

Photo Courtesy of Gulf Oil Canada Ltd.

SUMMARY

I have tried to outline the main factors to be considered in the panel discussion and would like to underline the following:

1. Our existing inventory is patchy and we should develop a well-planned and staged development of the inventory to have adequate information available to plan to meet power demands as they arise.
2. Lead time is now at least five years and preliminary information on likely sites is needed in order to complete projects in time to meet new load demands.
3. Hydro power as a renewable resource should normally be ranked in priority ahead of fossil fired thermal stations.
4. Hydro plants give greater security, longer life and are easier to operate and maintain than thermal stations.
5. Hydro plants costing in the range of $1,500 per kW are competitive with oil fired thermal plants based on a levelized energy cost.
6. Studies to develop ideas of environmental enhancement should be carried out along with preliminary studies in order to avoid possible rejection of certain sites.
7. Hydro stations can and should be designed to make maximum use of local materials.
8. Studies for development of hydro power to suit industrial needs should also recognize the side benefits of providing lower cost power to existing load centres utilizing new transmission line facilities.

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TABLE I

SUMMARY OF HYDRO RESOURCES — MW

TOTAL POTENTIAL OF HYDRO SITES STUDIED

	Level 1	Level 2	Level 3	TOTAL STUDIED	TOTAL EXISTING	TOTAL THEORETICAL Potential at 0.6 Capacity Factor
YUKON TERRITORY	9,800	620	20	10,440	56	11,000
NORTHWEST TERRITORIES*	2,800	2,500	660	5,960	49	14,900
TOTAL	12,600	3,120	680	16,400	105	25,900

* Portions of rivers tributary to the MacKenzie Basin located in the Yukon Territory are included in the Yukon Territory potential.

DEFINITION OF LEVELS USED IN GROUPING HYDRO SITES STUDIED

Activity	Level 1 (Pre-Inventory)	Level 2 (Inventory)	Level 3 (Pre-Feasibility)
Field	Nil to one day visit	Several weeks reconnaissance	One season's work. Subsurface investigation by drilling. Search for construction materials.
Hydrology	Treated on area basis	Site or river study	Detailed
Survey	Nil to barometer river profiling	Controlled barometer. Ground control for aerial photo mapping	Ground surveys
Mapping	Using existing 1:50,000 or 1:250,000 scale	20 ft contours	10 to 20 ft contours for detailed design layout
Study Scope	Territory or large area	Individual sites on a river	One development scheme for site or river
Cost Estimate	Nil to order of Magnitude	Preliminary detailed	Detailed

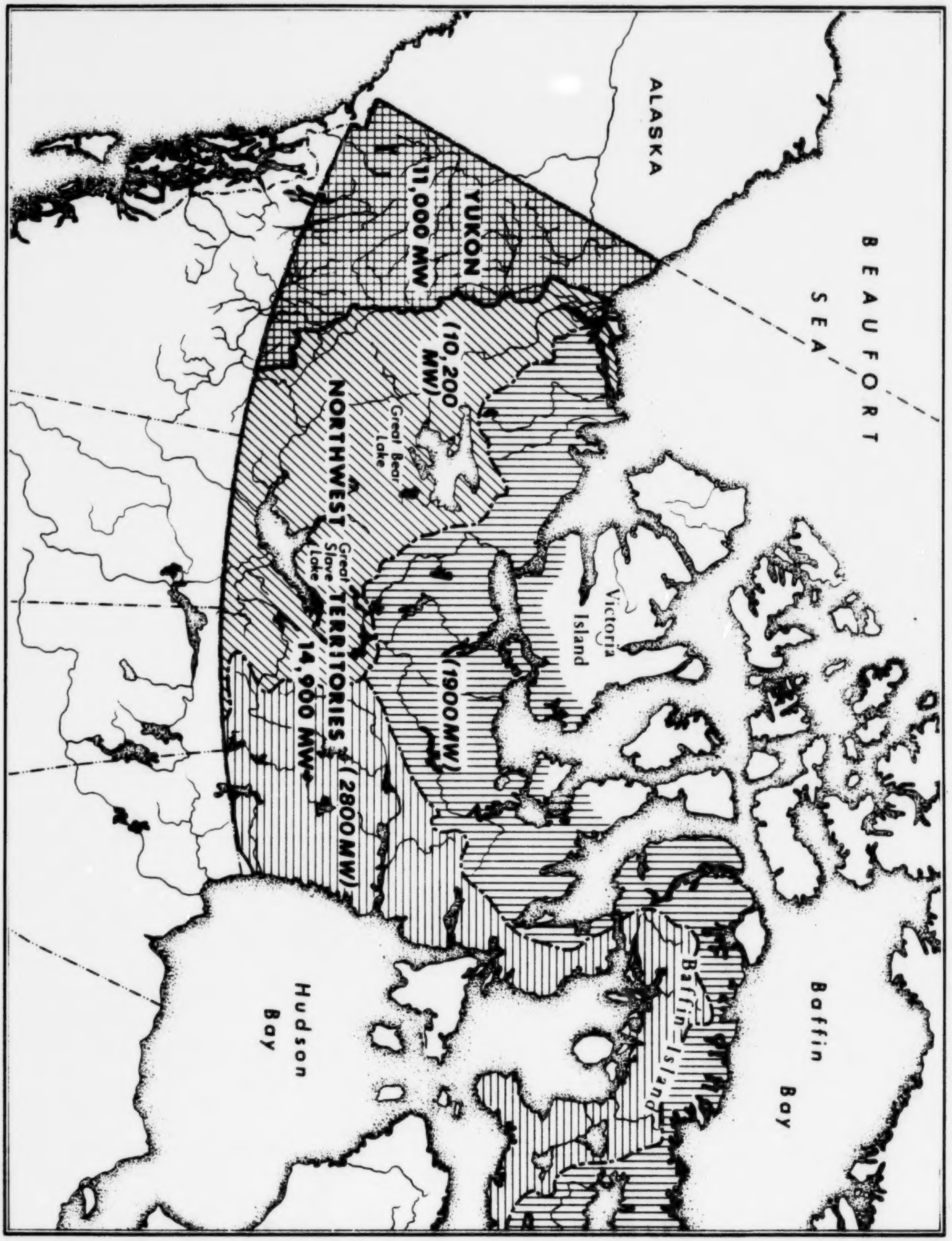
BEAUFORT SEA
ALASKA
YUKON
11,000 MW
(10,200 MW)
Great Bear Lake
NORTHWEST TERRITORIES
14,900 MW
Great Slave Lake
Victoria Island
(1900MW)
(2800MW)
Baffin Island
Baffin Bay
Hudson Bay

FIGURE 1
Hydro resources in the canadian north

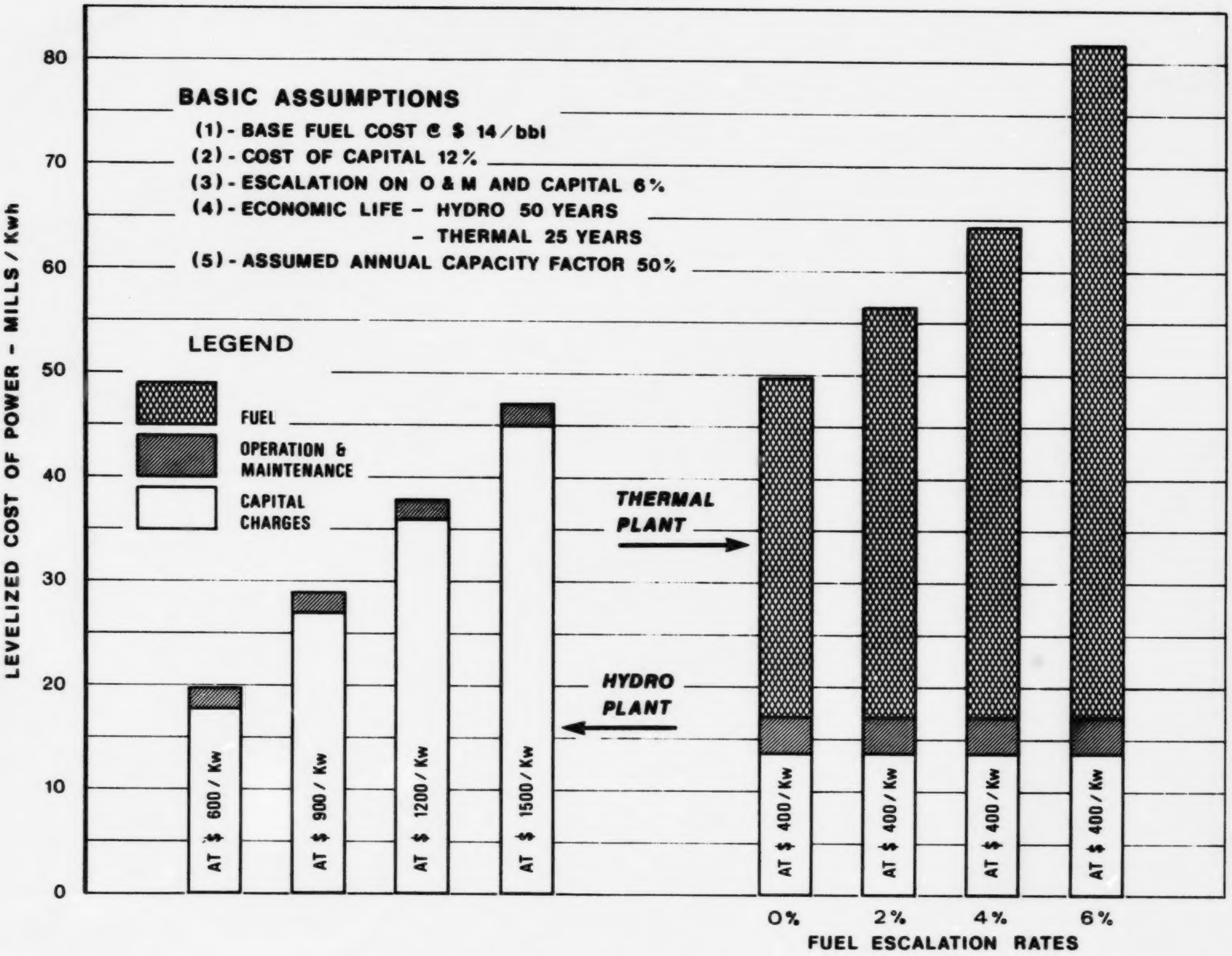

FIGURE 2 – Power cost comparison, Hydro vs Thermal

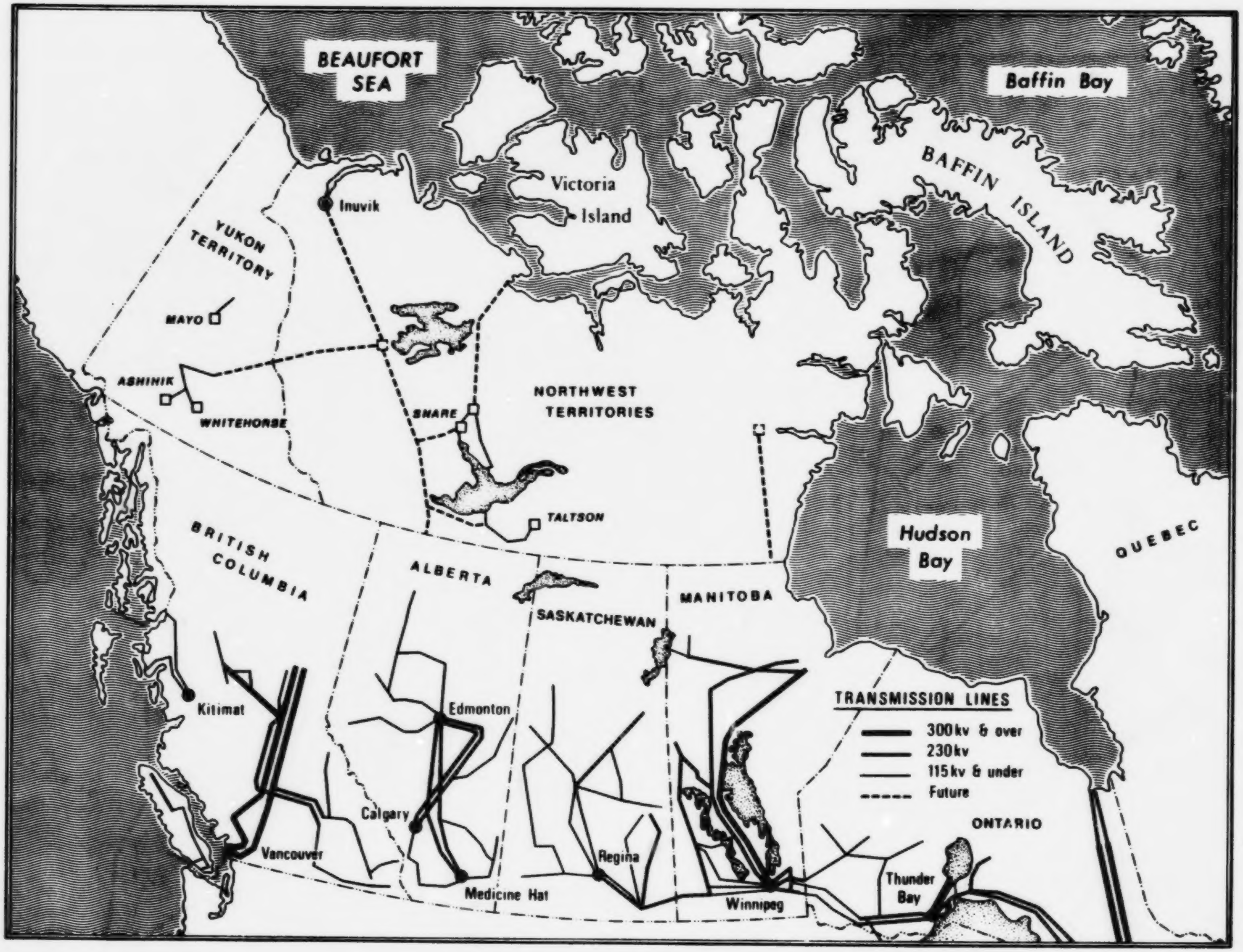
BEAUFORT SEA
Baffin Bay
Victoria Island
BAFFIN ISLAND
Inuvik
YUKON TERRITORY
MAYO
ASHIHIK
WHITEHORSE
SNARE
NORTHWEST TERRITORIES
TALTSON
Hudson Bay
QUEBEC
BRITISH COLUMBIA
ALBERTA
SASKATCHEWAN
MANITOBA
ONTARIO
Kitimat
Vancouver
Edmonton
Calgary
Medicine Hat
Regina
Winnipeg
Thunder Bay
TRANSMISSION LINES
300kv & over
230kv
115kv & under
Future

FIGURE 3
Existing and possible future transmission lines

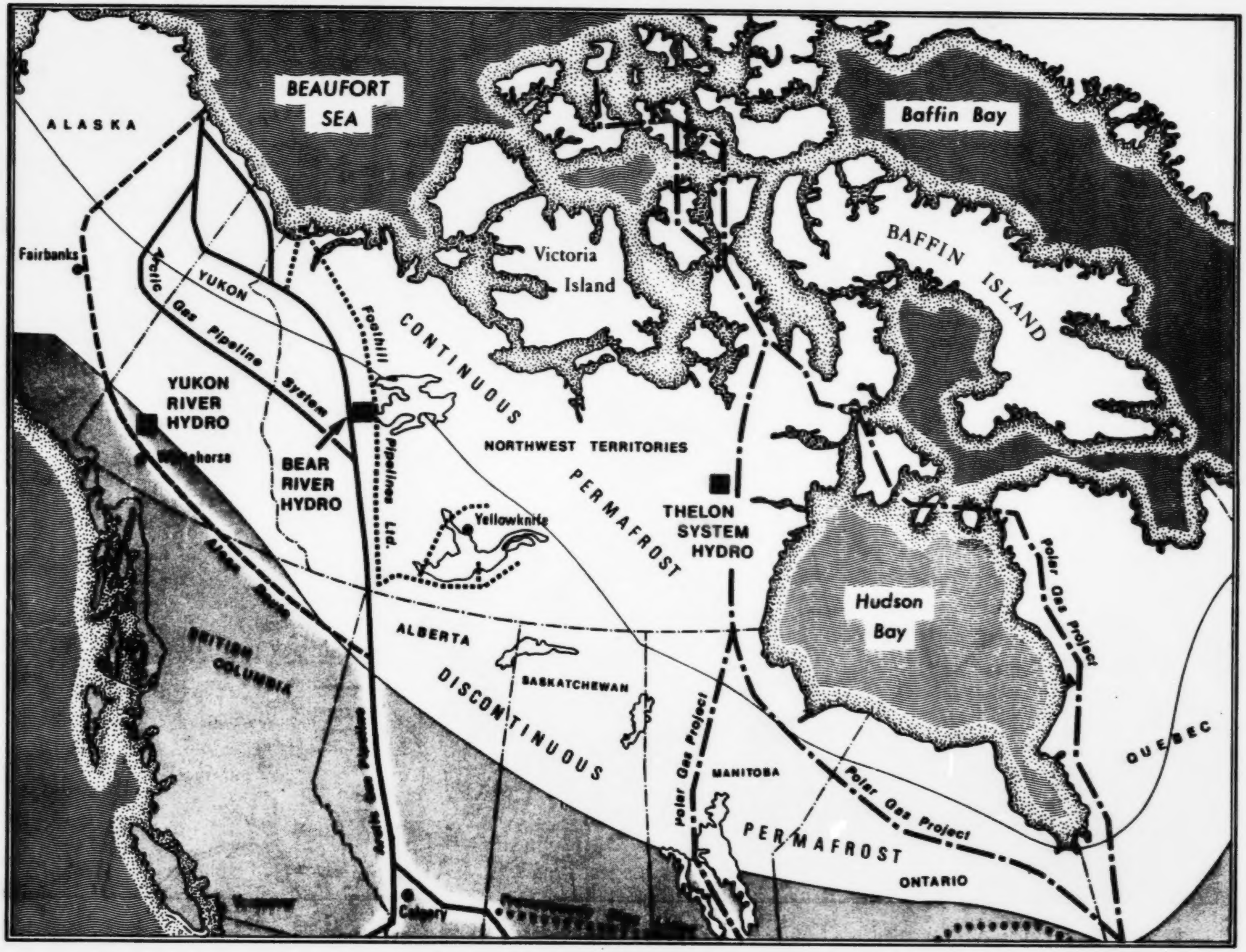
BEAUFORT SEA
Baffin Bay
ALASKA
Fairbanks
YUKON
Arctic Gas Pipeline System
Victoria Island
BAFFIN ISLAND
Foothill Pipelines Ltd.
CONTINUOUS
YUKON RIVER HYDRO
Whitehorse
BEAR RIVER HYDRO
NORTHWEST TERRITORIES
PERMAFROST
THELON SYSTEM HYDRO
Yellowknife
Hudson Bay
Polar Gas Project
ALBERTA
BRITISH COLUMBIA
SASKATCHEWAN
DISCONTINUOUS
Polar Gas Project
MANITOBA
Polar Gas Project
QUEBEC
PERMAFROST
ONTARIO
Calgary

FIGURE 4
Alternative gas pipeline routes with adjacent hydro potential

APPENDIX C

SUMMARIES OF PREVIOUS STUDIES

APPENDIX C - SUMMARIES OF PREVIOUS STUDIES

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C.1 INTRODUCTION

In this appendix, summaries are presented of previous inventory studies relevant to this Review. Not summarized are the various feasibility and prefeasibility studies of individual sites carried out since 1980. It is assumed that these studies have been based on adequate, up-to-date data, and are at least to Inventory Level, Category C.

Each summary describes the purpose and scope of the study, the field work carried out, the hydrological calculations performed, the topographic and geological mapping produced, the design criteria used, the basis for the cost estimates produced, and the findings of the study. In an attempt to bring the studies to a common basis for evaluation, each summary also includes an assessment of the depth of the study, using the categories described in Section 312 of the main report.

The information contained in the summaries has been further condensed to produce Table 4-1, contained in the main report.

C.2 SUMMARIES

C21 INTERIM REPORT ON HYDROELECTRIC POWER POSSIBILITIES OF KLUANE RIVER, YUKON TERRITORY: KLUANE CANYON DAM SITE

Water Resources Branch, Department of Northern Affairs and National Resources. May 1962.
Study Designation: KL62

.1 Purpose and Scope

The 1962 Water Resources Branch study of the Kluane River investigated only the Kluane Canyon site, with storage being provided on Kluane Lake. Investigations were carried out between 1958 and 1962.

.2 Field Work

In 1958, the Water Resources Branch carried out a stadia survey of the damsite, tying into geodetic control by spirit levelling. Five seismic refraction lines were also run. In 1961, the Geological Survey of Canada carried out detailed geological surface mapping of the site.

.3 Office Work

.31 Hydrology Hydrologic calculations carried out during the study were based on 7 years of hydrometric data collected from 1952 to 1959 at the outlet of Kluane Lake. No flow data was available for the Duke River. Its flow was eliminated from the calculations to compensate for a possibly drier cycle than that recorded. The firm flow for the project was calculated based on a 2 year critical period with 3.8 m of storage. The design flood was determined from a maximum projected rainfall over the entire drainage basin. The projection was based on minimal precipitation data.

.32 Topography and Geology From the stadia survey, topography at a scale of 1:1,200, and with 10 foot contours was produced. The geological mapping was prepared using this topography as a base. Delineation of the reservoir was accomplished using existing 1:50,000 scale National Topographic System maps with 100 foot contours.

.33 Design The proposed structure was a mass concrete dam with an integral spillway and intake/powerhouse structure. A 50% load factor was assumed. A drawing showing the general layout and sections of the structures is contained in the report.

.34 Cost Criteria and Estimates A detailed cost estimate, including quantities for earthworks, concrete, and steel, is presented in the report. The estimate is based on 1961 price levels. Interest during construction, and contingencies were included. Reservoir clearing and socio/environmental mitigation costs are not included. The amortization period and interest rate are not specified.

.35 Socio/environmental Factors Socio-environmental factors were not considered in the study, and mitigation costs, including reservoir clearing, were not included in the cost estimate.

.4 Findings

A 16.5 MW plant was found to be technically feasible, at a capital cost of $10.7 million and with a firm energy cost of 1.27¢/kWhr.

.5 Comment

The study was carried out to Inventory Level, Category C. The site might well bear further investigation to determine if a greater head and capacity could be obtained by a canal. The flow regulation would provide downstream benefits to the lower Yukon mainstem projects.

C22 INTERIM REPORT ON HYDROELECTRIC POWER POSSIBILITIES OF ROSS RIVER, YUKON TERRITORY: PREVOST CANYON DAM SITE; ROSS CANYON DAM SITE

Water Resources Branch, Department of Northern Affairs and National Resources. November 1962.
Study Designation: RP62

.1 Purpose and Scope

The purpose of the study was to carry out investigations of any promising sites on the Ross River to a level sufficient to make preliminary layouts, power evaluations and detailed cost estimates. Sites selected were at Ross Canyon and Prevost Canyon. Investigations were carried out between 1958 and 1962.

.2 Field Work

Field investigations carried out during the study included aerial and ground reconnaissance, and topographic surveying. At the Ross Canyon site, geological mapping, including a small seismic survey, was conducted.

A stream gauging station was established in 1961 on the Ross River, near its mouth.

.3 Office Work

.31 Hydrology Since a streamflow gauging station had only been established on the Ross River in 1961, and therefore little data was available, Ross River flows were estimated using seven years of hydrometric data from the Pelly River. Flows were correlated by comparing miscellaneous measurements on the Ross River with corresponding ones on the Pelly. A somewhat arbitrary proportioning of the estimated Ross River flows was then made for the two sites under investigation. Mass curves were calculated for the critical period at each site, from which firm flows were determined. Because sufficient hydrometric data was not available, flood flows were determined by the routing of a maximum assumed storm. No precipitation records were available for the selection of this storm.

.32 Topography and Geology From the field surveying, 1:1,200 scale topographic mapping with 10 foot contours was produced for the two damsites. For Ross Canyon, this topography was supplemented with geological mapping. Mapping of the reservoirs was carried out from preliminary 1:50,000 National Topographic System maps.

.33 Design No layouts are included in the copy of the report reviewed, but reference is made in the text to a general layout for each site. Rockfill dams were selected for both sites, with concrete closure dams at the Prevost Canyon site. A 50% load factor was used in sizing the generating units.

.34 Cost Criteria and Estimates Detailed cost estimates, including quantities for several items, were provided for both sites. The estimates were based on 1961 price levels. Interest during construction, and contingencies are included. Clearing, and socio-environmental costs are not included.

.35 Socio-environmental Factors Socio-environmental factors were not considered in the study, and mitigation costs, including reservoir clearing, were not included in the cost estimate.

.4 Findings

A 12.4 MW plant at Prevost Canyon and a 38 MW plant at Ross Canyon were found to be feasibile. For Prevost Canyon, the capital cost was estimated at $9.9 million, with firm energy at 1.26¢/kWhr. For Ross Canyon, the capital cost was estimated at $21.7 million, with the energy cost at 0.82¢/kWhr.

.5 Comment

The Ross Canyon site has been recently investigated to pre-feasibility level, thus superceding this Inventory Level investigation.

The Prevost Canyon site did not receive as close a field investigation as the Ross Canyon site and the study in this respect falls very slightly short of Inventory level, Category C. In light of its proximity to potential mining loads in the MacMillan Pass area, further study of the Prevost Canyon site may be warranted.

C23 YUKON RIVER BASIN REPORT

Water Resources Branch, Department of Northern Affairs and National Resources. December 1962.
Study Designation: YB62

.1 Purpose and Scope

The 1962 Yukon River Basin Study was aimed at determining the major possibilities for hydro power development within the Canadian portion of the Basin, with particular attention to the effects of proposed diversion schemes from the headwaters. A total of 17 major projects were investigated for maximum development of the Yukon River main stem and its major tributaries. An alternative development plan was examined which utilized the flows remaining in the Yukon River main stem, assuming construction of either the Yukon-Taiya or Yukon-Taku diversion schemes. A much less detailed examination was made of about 35 minor project sites in the Basin.

The investigations were carried out over a seven year period, to a level or such that there would be confidence in the comparison of sites and alternative plans. No investigations were carried out of other uses of the water resource, such as navigation and fisheries.

.2 Field Work

The field program for the 17 major projects was extensive, and included: ground surveys (5 years); geological appraisal and mapping, including seismic probing, (3 years); and three seasons of other field work. The latter included some construction materials searches, reservoir surveys, and the setting up of additional hydrometric stations.

Aerial photographs and barometric levels were used for storage determinations. Damsites were mapped using stadia, with ties to geodetic control obtained by spirit levelling.

No foundation drilling was carried out, except at Miles Canyon.

Field work for the minor projects was generally limited to aerial reconnaissance, although some ground investigation were carried out at a few of the more accessible sites.

.3 Office Work

.31 Hydrology Design flows for the various sites were determined for a 13 year period from 1944 to 1957. Where available, data for the full period was used to extrapolate shorter records at other locations. Diversion design floods were taken as the maximum recorded flow. Spillway design floods were calculated empirically from the maximum recorded flow.

.32 Topography and Geology From the stadia surveys of the various damsites, topographic maps at scales of from 1:1,200 to 1:2,400, depending upon the site, and with contour intervals of 10 feet, were produced. Geological surface mapping was superimposed on this topography. Mapping of potential reservoir boundaries was carried out using 50 foot form lines marked onto airphotos. For minor sites, where stadia surveys were not carried out, use was made of available National Topographic System mapping.

.33 Design A few basic design criteria are given in the report, including the choice between earthfill, rockfill and concrete dams. General arrangements, cross-sections, and elevation plans are included for each major project. A load factor of 75% was assumed in sizing the generating equipment.

.34 Cost Criteria and Estimates Detailed cost estimates, with quantities for about half of the items, are provided in an appendix to the report. The costs were based on 1961 prices in the Pacific Northwest and British Columbia, with unspecified adjustments made to reflect the Yukon location. An amortization period of 50 years and an interest rate of 5% were used. Interest during construction, and contingencies were included.

.35 Socio-Environmental Factors No allowances were made in the cost estimate for navigation or fish passage facilities, or other socio-environmental mitigation, although reservoir clearing was included.

.4 Findings

The alternative or "Modified" development plan is compared with the "Major Plan", revealing that the diversion, assumed as 680 m^3/s, would reduce the main stem power potential by about 50% (ie. from 6,069 MW installed to 3,453 MW installed), with an increased firm energy cost from 4.6 mills to 5.5 mills/kWhr. An economic comparison of individual sites is possible on the basis of cost per kW installed, although not for any sites considered but not selected for detailed evaluation. There is no attempt to rank sites in order of attractiveness. Sites not fitting an optimum development scheme are not described.

It is interesting to compare below the "Major"and "Modified" schemes in conjunction with the output from one of the diversion schemes established in the 1966 study of the Yukon-Taiya and Yukon-Taku projects(YT 66).

Development Plant		Installed Capacity (MW)
"Major Plan"		6070
"Modified Plan"	3453	
plus Yukon-Taiya	4050	
		7500

.5 Comment

The study was quite extensive on the 17 major projects, being at least to inventory level, Category C but closer in most aspects to Category D. The minor sites and diversion schemes were studied only to a reconnaissance level, Category B.

Caution must be used in assuming the full potential suggested by the study, since flooding of communities and wildlife habitats, and adverse effects on anadromous fish have not been examined. These impacts could be extensive with the projects proposed.

C24 REPORT ON HYDROELECTRIC POWER RESOURCES OF THE PORCUPINE, PEEL AND RAT RIVER REGION, YUKON AND NORTHWEST TERRITORIES

Water Resources Branch, Department of Northern Affairs and National Resources. April 1965.
Study Designation: PP65

.1 Purpose and Scope

The 1965 Water Resources Branch report sets down the results of a preliminary assessment of the major hydroelectric possibilities in the Porcupine, Peel and Rat River region. The intent was to carry out studies sufficient to provide a reasonable indication of the magnitude of the hydro potential and the costs of development. The studies cover the area drained by the Porcupine River in Canada, which was not included in the 1962 Yukon River Basin Study(YB 62). Examination was made of a 5-stage project diverting water from the Porcupine and Peel Rivers to the Rat River, for generation in the Northwest Territories of about 2,000 MW, and alternatively a non-diversion development with two plants on the Porcupine River (300 MW) and two plants on the Peel River (150 MW).

The studies extended over more than three years.

.2 Field Work

Two seasons of field investigations were carried out, which included aerial photography, aerial and ground reconnaissance, ground and barometer surveys, river profiling, limited seismic investigation, and geological appraisal. Stream flow gauging stations were established. No drilling was undertaken.

.3 Office Studies

.31 Hydrology Hydrological studies were based on a three-year record, with flows synthesised to cover an eight-year period from 1955 to 1963. Firm flows at the various sites were established as 90% of the average water year flow for the eight-year period. A 20% contingency was incorporated into the storage calculations to allow for a drier cycle than that recorded. Flood flows were not calculated.

.32 Topography and Geology From the ground surveys, topographic/geological mapping was produced for the major damsites at scales of 1:1,200, 1:1,800, or 1:2,400, and with 10 foot contours. Potential reservoirs and diversion routes were mapped by photogrammetry and barometric surveying.

.33 Design Basic design criteria relating to bedrock, overburden and permafrost foundations are given in the report. Concrete, rockfill and earthfill dams were utilized. General arrangements, sections and elevations are given for each diversion scheme site. For sizing the power facilities, a 65% plant factor and an 87% efficiency factor were used.

.34 Cost Criteria and Estimates Cost and estimating criteria given in the report are limited to a 50 year amortization period with a 5% interest rate, and utilizing 1964 price levels. No detailed estimates are given, but capital costs for both diversion and non-diversion schemes are tabulated. No indication is given as to whether reservoir clearing is included.

.35 Socio-Environmental Factors Socio-environmental factors were not considered in the study.

.4 Findings

The study found that four times as much firm energy could be obtained from the Porcupine River when diverted down the Rat River, and at a cost of 0.5 to 0.6¢/kWhr compared with about 0.7 to 0.8¢/kWhr for the non-diversion schemes.

Non-diversion development on the Peel River was not investigated to a level where comparison of costs between diversion and non-diversion schemes could be made with confidence; however, costs of about 0.6¢/kWhr were estimated.

The magnitude of this power resource and its reasonable cost relative to alternate sources of energy were noted, as was the absence of a current load requirement. However, the presence of the Huge Snake River iron ore deposits, some 320 km away, was pointed out.

.5 Comment

This is generally an Inventory Level study, Category C, but some sites fall into Category B. Extensive work was done, including substantial field investigations. Only a very short hydrological record was available.

Flooding of the Old Crow area could be a major hurdle for the Porcupine site, and salmon passage could present a major problem for both diversion and non-diversion schemes.

C25 A PRELIMINARY APPRAISAL OF THE YUKON-TAIYA AND YUKON-TAKU STORAGE AND POWER SCHEMES

Water Resources Branch, Department of Mines and Technical Surveys. August 1966.
Study Designation: YT66

.1 Purpose and Scope

The 1966 Water Resources Branch Study of the Yukon-Taiya and Yukon-Taku projects was an office assessment carried out to provide a reasonable basis for technical comparison of the two alternative proposals for upper Yukon River hydro power development by diversion through Alaska and British Columbia to tidewater. While it was an office study without field investigations, it made use of previous data, plans and reports prepared by the Water Resources Branch, Northwest Power Industries Ltd., the United States Department of the Interior, the Geological Survey of Canada, Alcoa and others.

The international Yukon-Taiya scheme was studied as a three-stage development with a firm potential of 3,410 MW at 85% load factor. The Yukon-Taku scheme was studied as a seven-stage development, entirely in Canada, with a potential of 2,930 MW of firm power. Both schemes involve diverting water from the upper Yukon River watershed through tunnels in the Coast Mountains and then down to as close to sea level as practical, giving a head of about of 600 m.

The studies were carried out over a period of about 2 years.

.2 Field Work

No field work was carried out specifically for the study, but field data, mapping, geological appraisals, etc., from previous studies were utilized.

.3 Office Work

.31 Hydrology Available hydrometric data was compiled for the period 1944 to 1964 for a number of base stations in the upper Yukon River basin. Where records were incomplete, the data was extended by correlation and extrapolation. A runoff model was produced, using records from 1956 to 1962, to determine runoff distributions. Mass curves and reservoir operating curves were calculated, and firm flows determined. Allowances were made for contingency storage and minimum compensation flows. Design floods were determined using routing hydrographs developed by the U.S. Army Corps of Engineers for the Rampart Canyon project in Alaska.

.32 Topography and Geology No new topographic or geological mapping was produced for the study; however, use was made of a number of detailed topographic, bathymetric and geological maps obtained from various sources, including Northwest Power Industries Limited, the Water Resources Branch of the Department of Mines and Technical Surveys, the Northern Canada Power Commission, the Surveys and Mapping Branch of the Department of Mines and Technical Surveys, and various United States government agencies. A complete listing of the maps is contained in an appendix to the report. The detailed maps had scales ranging from 1:490 to 1:6,000, and contour intervals of from 2 feet to 50 feet.

.33 Design Some basic design criteria are specified in the report. These generally conform to those used in the 1962 Yukon Basin Study(YB 62), and to engineering practice at the time. Tunnelling forms substantial parts of the projects. Full concrete lining with steel supports was assumed for 20% to 30% of the tunnel lengths. An overall efficiency of 88% was assumed for the generating equipment.

For each project, general arrangement plans, topographic site maps, sections, elevations and construction schedules are given.

.34 Cost Criteria and Estimates Summarized cost estimates, broken down into approximately 15 to 25 items, are presented in the report. Quantities are specified only for earth and rock excavation, and concrete. The estimates were based on late 1964/early 1965 prices. A 50 year amortization period was used, with an interest rate of 5%. Interest during construction, and reservoir clearing were included in the estimates.

.35 Socio-environmental Factors Political and environmental considerations were noted in the report as being important, but were not otherwise addressed or allowed for in the cost estimates. No allowances for example were made for navigation or fish passage facilities. The many jurisdictions involved, particularly in the Yukon-Taiya scheme, were noted, together with the specific problem of preserving the anadromous fish resources of the Yukon River. An obvious socio-political factor associated with the schemes would be the raising of Marsh, Tagish and Bennett Lakes by 14 m, and the provision of 4.6 m of drawdown.

.4 Findings

The conclusion of the study was that the Yukon-Taiya scheme has a power potential of 4,050 MW installed capacity (3,410 MW firm) about 20% greater than the Yukon-Taku scheme 3,690 MW installed capacity (2,930 MW firm), and at a 30% lower firm energy cost 0.26¢/kWhr versus 0.36¢/kWhr. Both projects present attractive energy costs, but require a major load within a reasonable distance.

.5 Comment

The studies are classed as Pre-feasibility Level, Category D.

C26 POWER SUPPLY FOR THE YUKON: A PRELIMINARY APPRAISAL AND ADDENDUM TO PRELIMINARY APPRAISALS

Montreal Engineering Company, Limited. March 1966 and July 1965.

Study Designation: PS66

.1 Purpose and Scope

The 1966 Montreal Engineering study comprised an office investigation and field reconnaissance for a potential mining/smelter load in the Vangorda Creek region. Two possibilities were considered:

- a 30-50 MW plant at 75% load factor; and
- a 100 MW plant at 95% load factor.

Hydro sites identified in the 1962 Yukon River Basin Study(YB 62) were re-examined to identify those appropriate to meet the required load at costs competitive with thermal power generation. Some 10 sites were examined, the choice being narrowed to three or four sites, including Granite Canyon on the Pelly River and Five Finger Rapids on the Yukon River.

The work was completed in under one year.

.2 Field Work

The field work was limited to brief reconnaissance visits to six of the sites.

.3 Office Work

.31 Hydrology Hydrology calculations carried out for the 1962 Yukon Basin Study(YB 62) were updated using additional hydrometric data where available, and by correlation where not available. Mass curves were calculated for each site for the new and extended data, and firm flows were determined. Design floods were taken to be the same as those calculated in the 1962 Yukon Basin Study, except for sites on the Ross River which were increased due to a higher recorded flood in 1964.

.32 Topography and Geology No new topographic or geological mapping was produced for the study. The investigation was based on available mapping for 5 of the sites, produced by WRB/GSC at scales of 1:1,200 or 1:2,400, and with 10 foot contours. Except for one site (Five Finger Rapids), the mapping has been produced subsequent to the 1962 Yukon Basin Study.

.33 Design Structure types and layouts were generally similar to those used in the 1962 Yukon Basin Study(YB 62), with rockfill, concrete and earthfill dams being utilized. General layouts are presented in the report for 5 sites (Ross Canyon, Prevost Canyon, Fraser Falls, Granite Canyon, and Five Fingers Rapids). An alternative layout is shown for Granite Canyon. For the Five Finger Rapids site, elevation drawings and sections are also given.

.34 Cost Criteria and Estimates Summarized cost estimates, broken down into approximately twenty items, are presented for the five sites listed above. No quantities are given. Interest during construction, and contingencies are included in the estimates.

Reservoir clearing, interim replacement, and environmental costs are not included. The estimates were based on a 40 year amortization, with an interest rate of 5.625%.

.4 Findings

The projects which appeared most promising for the assumed loads were Granite Canyon and Five Finger Rapids, with the possibility that a plant on the Frances River might, after further investigation, be found suitable. Estimated costs for firm energy ranged from 0.6 to 1.2¢/kWhr, which was found to be lower than thermal power, for higher load requirements.

.5 Comment

The investigation was primarily an office study, using data from the 1962 Yukon Basin Study(YB 62) to meet specific load situations. Hydrology was updated for all sites. A lower Five Finger Rapids scheme, with correspondingly less flooding than considered previously, was examined. Frances River sites were seen to have promise.

Almost all sites examined in the study, except for Prevost Canyon, have subsequently been studied to greater depth. The study is judged to be at Category A level, except in the cases of Granite Canyon and Five Fingers Rapids, which are considered to be to Category B level.

C27 HYDROELECTRIC RESOURCES SURVEY OF THE CENTRAL YUKON TERRITORY

T. Ingledow & Associates Limited. January 1968.
Study Designation: CY68

.1 Purpose and Scope

The 1968 Ingledow study was carried out to examine the potential for hydroelectric development in the central area of the Yukon, within a radius of 280 km (175 miles) of Carmacks, but excluding the main stem of the Yukon River. Potential projects were to be described, and cost and power demand estimates prepared. Field reconnaissance of the area and sites was to be carried out.

Some 55 sites were examined, and of these some 43 were selected as worthy of inclusion in the inventory listing. No projects less than 5 MW were considered.

This Reconnaissance Level study was carried out in a 5 month period.

.2 Field Work

With the limited time available, field work was restricted to a helicopter reconnaissance. During the helicopter visits, sketches of the sites were produced which were later used in the conceptual project layouts. In addition, barometer profiles were made along the major rivers and diversion routes, using points taken at intervals of three to five miles (4.8 to 8.1 km). Wherever possible, these elevations were tied into geodetic control. Barometric elevations were also taken at the locations of key structures.

.3 Office Work

.31 Hydrology Hydrologic calculations for the study were made from available hydrometric data up to the end of the 1965 water year, for various base stations on the Yukon, Takhini, Pelly, Stewart and Teslin Rivers. Mass curves were produced from which firm flows were determined for the various sites. At sites where sufficient storage was available, the firm flow was taken to be the average dry year flow. Where sufficient storage was not available, the firm flow was determined from the ratio of available storage to required storage. Design floods were taken to be equal to the 1000 year floods, as determined from a probability analysis of flows on the Yukon and Stewart Rivers.

.32 Topography and Geology No new topographic or geological mapping was generated by the study. The study report indicates that 1:50,000 scale National Topographic Survey mapping with 100 ft contours was available for the northern and southern parts of the study area, but no documentation is contained in the report. At many sites, available mapping was only to a scale of 1:250,000 with 500 foot contours. Detailed topographic and geological mapping was available for several sites which had previously been studied by the Water Resources Branch/Geological Survey of Canada, mostly as part of the 1962 Yukon Basin Study(YB 62).

At two sites (Tay River Diversion and Hess Two Mile Canyon), geological evaluations were made by Dolmage, Campbell & Associates; however, these were evidently limited to brief site inspections, and apparently no mapping was produced.

.33 Design The design criteria used are set out in the report in detail. Only rockfill and concrete gravity dams were consdered. A description of each potential project is given but no layout drawings are provided. The descriptions cover flows, dam heights, conduit lengths, power potential and other key data. More detailed descriptions are given for four selected projects: Primrose; Detour; Hoole Canyon; and Aishihik.

.34 Cost Criteria and Estimates Basic criteria used for the cost estimates and the cost of power computations are given in some detail; however, estimate summaries are given only for the four selected sites. For most projects only a total capital cost is given.

.35 Socio-environmental Factors Socio-environmental factors were not examined and mitigation costs were not allowed for; however, reservoir clearing costs were included.

.4 Findings

A comparison tabulation of the 42 potential projects is given in the report, showing capital cost, cost/MW installed and cost/kWhr. Some of the sites listed however, have impediments mentioned in the project descriptions which make them unattractive and unlikely to be developed (e.g. conflict with better sites, lack of storage, location, etc.).

.5 Comment

This study, carried out in only 5 months and with less than one day field work per site, is not judged to be at Inventory Level, but rather at Reconnaissance level, Category B.

C28 FRANCES RIVER DEVELOPMENT

Montreal Engineering Company, Limited. December 1969.
Study Designation: UC69

.1 Purpose and Scope

The Frances River had been noted in various reports as being promising for hydroelectric power development, and a preliminary reconnaissance of potential sites had been carried out in 1966. In 1969, a study was carried out by Montreal Engineering Co., Ltd. to investigate the Upper Canyon site and to produce cost estimates for 1 and 2 unit plants, with and without the cost of transmission to Whitehorse.

.2 Field Work

A field reconnaissance of the Upper Canyon site was made in June 1969. In August 1969, barometric levels were established, and a stadia survey of the damsite was carried out. An initial construction materials search was also made, by inspection of road cuts and river banks.

About one week was devoted to the field work.

.3 Office Work

.31 Hydrology Hydrometric records for the Frances River were available for only a 6 year period up to 1968. Because of the shortness of the period, the records were extended to 11 years (1957-1968) by correlation with flows on the Hyland River. The design flood for the site was determined from a frequency analysis of the extended record.

.32 Topography and Geology From the stadia survey data, 1:1,200 scale topographic mapping, with 10 foot contours, was produced of the site. The reservoir was mapped from existing 1:250,000 National Topographic System maps with 500 foot contours. No geological mapping of the site was carried out. The Geological Survey of Canada had previously mapped a site approximately 1.6 km upstream, and for the purposes of the study, it was assumed that the geology of the two sites was similar.

.33 Design The proposed project is well illustrated by a series of general layout and detail plans contained in the report. A construction schedule is also included. A capacity factor of 60% was used in the design.

.34 Cost Criteria and Estimate A detailed estimate, with quantities for most items, is given in the report. The estimate was based on 1969 price levels. An interest rate of 8% and a 50 year amortization were assumed. Interest during construction, and contingencies were included in the estimate.

.35 Socio-environmental Factors Reservoir clearing, and socio-environmental mitigation were not considered in the study.

.4 Findings

A 58 MW plant, comprising two units, was found to be technically feasible. Firm energy, at the plant, was estimated to cost 0.73¢/kWhr. However, no reservoir clearing costs were included in the cost estimate, and these could be very heavy, possibly changing significantly the economic viability of the site.

.5 Comment

The Upper Canyon project, while one of the most attractive for moderate cost power, depends on a 14 m increase in the level of Frances Lake, and high reservoir clearing costs. It could be superceded by the False Canyon project which has the same potential capacity, at higher cost, but with lower environmental impact. The general level of this study is Inventory, Category C, although in some aspects it would be rated Category D.

C29 POWER SURVEY OF THE LIARD RIVER BASINS: YUKON AND NORTHWEST TERRITORIES

T. Ingledow & Associates Limited. February 1970.
Study Designation: LB70

.1 Purpose and Scope

The 1970 Ingledow study was a survey of power sites and demands in the Liard River Basin. In the Yukon, approximately 15 sites were examined and of these, 8 were selected as appropriate to the inventory: three on the Frances River; one on the Liard River; one on the Coal River; and three on the Beaver River. The level of the studies was intended to be that which would permit reasonable cost comparison among the sites, and with thermal power alternatives.

Only 10 months were available for this 30 site investigation.

.2 Field Work

The field work consisted of a helicopter reconnaissance, carried out over a 6 week period in the summer of 1969. Engineering and geological appraisals were made of the various sites, and photos were taken and sketches produced. Barometric levelling was carried out to obtain river profiles, and to provide site elevations for subsequent mapping from aerial photographs.

.3 Office Work

.31 Hydrology Mean flows for the various sites under consideration were determined by correlation with 18 years of hydrometric data, up to the end of 1968, for two base stations; one on the Hyland River, and one on the Liard River. The correlation was based on a proportioning of drainage areas. Beaver River flows were determined by correlation from Coal River flows. Mass curves were calculated for the critical periods at the various sites to determine the firm flows. A 1000 year return period was selected as the basis for the design floods. Peak Liard River flows were plotted, and then extended to the ungauged rivers on a unit area basis.

.32 Topography and Geology Available National Topographic System mapping of the Liard River basin was to a scale of 1:250,000, with 500 foot contours. In selected areas along the B.C./Yukon border, 1:50,000 mapping with 100 foot contours was available. For some sites, detailed topographic/geological maps produced by the Water Resources Branch/Geological Survey of Canada were available, generally at a scale of 1:1,200, with 10 foot contours. Where such mapping was not available, 1:4,800 scale topographic maps with 20 foot contours were produced for the study from aerial photographs. This mapping did not show any riverbed contours.

.33 Design Comprehensive design criteria, similar to those used in the 1968 Central Yukon Study(CY 68), are given in the report. Only rockfill dams with concrete diaphragms, or concrete gravity dams were utilized. Equipment was generally sized on the basis of a 60% capacity factor. For each site, an arrangement plan is provided in the report.

.34 Cost Criteria and Estimates In the study, project costs were estimated on the basis of southern Canadian costs, with a 25% increase on labour and equipment components to allow for the northern location. General guidelines used to estimate quantities are presented in the report, but no quantities are actually given. Only total estimated capital costs are specified. Interest during construction, contingencies, and reservoir clearing are included. An amortization period of 40 years, and an interest rate of 8.25% were used in the estimates.

.35 Socio-environmental Factors Socio-environmental factors were not considered in the study, although reservoir clearing costs were included in the cost estimate.

.4 Findings

The 8 projects found to be technically feasibly have a combined capacity of about 390 MW, with sites ranging in capacity from 14 MW to 120 MW. Firm energy costs were estimated at between 1.0 and 2.1¢/kWhr. The probable loads which might require the power were identified as mining and forest product developments, for which the area has potential.

.5 Comment

The study appears to have been somewhat more detailed than the 1968 Central Yukon Study(CY 68); however, with 30 sites having been examined in a 10 month period, and with a field program of between 1 and 2 days per site, the depth of the investigation barely meets Inventory Level, Category C for the Liard and Frances River sites with a level B rating on all other sites.

C210 THE DEVELOPMENT OF POWER IN THE YUKON

Sigma Resource Consultants Ltd. et al. January 1975.
Study Designation: SI75

.1 Purpose and Scope

The 1975 Sigma study was designed to set out the first phase of a planning program to establish the power resources of Yukon available to meet a range of possible power demands to the year 1990. It included the preparation of an inventory of all potentially attractive hydro-power sites, and the comparison of costs and environmental and social affects. A total of about 100 sites were identified, of which some 22 were in the Northwest Territories, adjacent to the Yukon border. Of the Yukon sites identified, 17 were selected for investigation, and updating and re-estimating of work carried out during previous studies; 24 had hydrology updated only; and 39 were dismissed as unpromising.

The study was carried out in about one year, and was limited to projects of 30 MW or more. The report comprised four volumes: the main report; Appendix 1 - Technical Information; Appendix 2 - Hydrology; and Appendix 3 - Environmental and Social Aspects.

.2 Field Work

Two field survey trips were made during the study, by fixed wing aircraft and by helicopter, covering over 30 sites. Some barometric levelling was carried out during these trips to confirm and supplement existing information on river profiles. The duration of each survey trip was less than one month.

.3 Office Work

.31 Hydrology Hydrologic calculations for the sites considered in the study were carried out for a 24 year period from 1950 to 1973. Where hydrometric data was not available for the full period, extensions were made by computer correlations from other stations. Data gaps were filled by pro-ration or interpolation. Firm flows at the sites were determined from a relationship established for the Pelly, Stewart, Teslin, Frances, and Ross Rivers between storage as a proportion of mean annual inflow, and firm flow as a proportion of the long term flow. Spillway design floods were taken to be twice the 1964 peak instantaneous flow after routing through a full reservoir. Diversion works floods were taken as equal to the 1964 peak instantaneous flow.

.32 Topography and Geology Except for one site (Tatshenshini I), no new topographic or geological mapping was produced for the study. Where available, existing Water Resources Branch/Geological Survey of Canada mapping at scales of from 1:1,200 to 1:2,400, and with 10 foot contours, was used. At other sites, available National Topographic System maps at scales of 1:50,000 with 100 foot contours, or 1:250,000 with 500 foot contours were used. For the Tatshenshini I site, topographic mapping at a scale of 1:4,800 with 25 foot contours was produced for the study from airphotos.

.33 Design Design criteria are not given in the report. Combined general location plans and simple line layouts are shown for 18 projects. A 60% capacity factor was used in selecting the size of generating units.

.34 Cost Criteria and Estimates Cost estimates, broken down into about a dozen items, are presented for 20 sites. No quantities are given. The estimates were based on 1973 price levels. Powerhouse and equipment costs were based on "unit cost curves" which are not explained. An amortization period of 50 years, with interest rates of 6% and 8% was used. Contingencies, and reservoir clearing are included. Interest during construction is not included.

.35 Socio-environmental Factors Socio-environmental factors are considered in some detail in the main report, with backup data in a substantial appendix. The probable effects of the 21 selected projects have been tabulated, but the input data, not being quantitative, is seen as inadequate to rank the sites for socio-environmental acceptability.

.4 Findings

The tabulation of the 10 selected primary sites, 4 secondary sites and 3 potential sites, compares the capital costs and the cost per installed kW. The range of the latter is from \$630/kW to \$1,500/kW. Compared with alternative energy sources, hydroelectric power is seen as the only local energy source of proven availability, with oil fuelled thermal power the basic substitute.

.5 Comment

The study covers a vast area and attempts to deal with about 100 possible sites. The main stem of the Yukon River receives only an aerial reconnaissance in a fixed wing aircraft, and only the Five Finger Rapids site is investigated. The main stem Yukon River sites examined in the 1962 Yukon River Basin Study(YB 62) account for about 50% of the total hydroelectric resources of the Yukon.

Socio-environmental factors receive considerable study, and the report deals more with them than with the technical feasibility. For example, of the 15 sections in the main report, 9 sections are devoted to other uses of the resource, primarily socio-environmental, and only 4 deal with the hydro inventory and load projections.

Considering the one year time limit and funding restrictions, it is not surprising that this study is judged only at Reconnaissance Level, Category B.

C211 MINING HYDRO POWER STUDY OF SMALL TO MID-SIZE DEVELOPMENTS IN EAST-CENTRAL YUKON

Monenco Consultants Pacific Limited. November 1980.
Study Designation: MH80

.1 Purpose and Scope

The 1980 Monenco mining hydro study was a reconnaissance study caried out to determine the ranking of four promising sites - Hoole Canyon, Ross Canyon, False Canyon, and Little Salmon - as a source of power for a proposed mining development in the east-central region of Yukon. Studies covered a six month period.

.2 Field Work

Field work for the study was limited to a helicopter reconnaissance, with barometric levels being taken at key locations.

.3 Office Work

.31 Hydrology Hydrologic calculations for the study were made using 14 to 20 years of hydrometric data up to the end of 1979. For False Canyon, Hoole Canyon, and Ross Canyon, data was available for the Frances River, Pelly River, and Ross River, respectively. This data was adjusted to the sites under consideration by a proportioning of the drainage areas. As no data was available for the Little Salmon River, calculations were based on gauging of the Big Salmon River. Firm flows were determined for the critical flow period, which for all of the sites was found to be the 6-months of November

1973 to April 1974. For the comparative purposes of the study, the spillway design floods were taken as the 1000 year flood, based on an extreme value probability analysis. Diversion design floods were taken to be the 25 year flood.

.32 Topography and Geology Using photogrammetry, 1:2,500 scale maps with 5 m contours were produced for the False Canyon and Ross Canyon dam sites. For the Hoole Canyon site, a 1:1,200 scale map with 10 foot contours produced by the Water Resources Branch/Geological Survey of Canada in 1965 was extended by photogrammetry. The Little Salmon site was studied using 1:5,000 maps with 5 m contours produced during the investigation of the Mid-Yukon Project(MY 80). Reservoirs were mapped from existing 1:50,000 National Topographic System maps, except for the upper part of the False Canyon reservoir for which only 1:250,000 mapping was available.

Geological mapping produced by the Geological Survey of Canada was available in topical report form for the False Canyon, Hoole Canyon and Ross Canyon sites. Mapping of the Little Salmon site geology was carried out as part of the Mid-Yukon Project study(MY 80).

.33 Design Detailed design criteria are not given in the report; however, a capacity factor of 60%, and an efficiency of 85% were used in the sizing of the generating equipment. A project layout plan is included for each site.

.34 Cost Criteria and Estimates Cost estimates, broken down into about a dozen items are provided for Hoole Canyon, Ross Canyon and Little Salmon. No quantities are given. For False Canyon, the favoured project, a detailed estimate with quantities is provided. All estimates are in 1980 dollars, with unit prices based on northern experience. Where applicable, estimated unit prices for the Mid-Yukon Project were used. A range of reservoir clearing costs are provided for fringe clearing to full clearing. An interest rate of 12% p.a. was used in the calculations.

.35 Socio-environmental Factors Evaluation of socio-environmental impacts was not a part of the study.

.4 Findings

Of the four sites, only Little Salmon could be dropped from immediate consideration, with the estimated cost per installed kW being about double that of the other three projects. Firm energy costs at Faro were found to be about 8¢/kWhr for the False Canyon scheme.

.5 Comment

The three most promising sites (False Canyon, Hoole Canyon, and Ross Canyon) have since been studied to Category D level(FC 82), (HC 82), and (RC 82), thus rendering this study obsolete. The Little Salmon site might be re-examined for a smaller development if such a requirement arose.